OPERATIVE TECHNIC

IN

SPECIALTY SURGERY

Edited by WARREN H. COLE, M.D., F.A.C.S., Professor of Surgery and Head of the Department, University of Illinois College of Medicine; Chief Surgeon, Illinois Research and Educational Hospitals, Chicago

With 67 contributing authors *SECOND EDITION*

Introduction by Allen O. Whipple

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To my wife

Clara

without whose patience and understanding editorship of this work could not have been accomplished

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VARICOSE VEINS AND VENOUS THROMBOSIS

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CARDIAC SEPTAL DEFECTS AND OPEN CARDIOTOMY
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SURGICAL APPROACHES TO THE JOINTS

Preface

This volume is devoted to the surgical specialties, although they are admittedly difficult to define and often overlap general surgery. In spite of the fact that the medical profession has for years been trying to curb the tendency toward specialization, this trend has progressed. Nevertheless, we must admit that progress is much more rapid when the individual worker devotes his entire time to the field under investigation rather than dissipates his time and energy in numerous fields which may not be related. Fortunately, the policy of having the specialist in training spend some time in general surgery, and vice versa, is gaining favor during recent years; it is nevertheless true that after completion of their training, surgeons in the two fields for the most part revert in practice to their original calling. Even those who make a special appeal to avoid specialism seem to be specialists themselves. Unfortunately, this specialism cannot be avoided if the surgical profession is to develop talent of the highest type, because the surgical field is becoming too broad for any one man to become proficient in more than one or two of its branches.

In spite of the inability to prevent specialism we should nevertheless insist that in his training period the specialist should have a significant exposure to general surgery and the general surgeon should have training in more than one or two specialties.

In this volume are included cardiovascular, thoracic, orthopedic, neurologic, plastic gynecologic and urologic surgery; ophthalmology and otolaryngology have been omitted largely because these two specialties are less distinctly related to general surgery than those included. The greatest change has been made in the massive enlargement of the material on cardiovascular surgery. In the few years lapsing since the first edition, that specialty has developed tremendously. We have reason to believe it will develop just as spectacularly during the next few years. With few exceptions, improvements and revisions in all chapters have been extensive. The number of illustrations has been increased markedly.

As in the first edition, we have presented herein pertinent data on indications for operation, pre- and postoperative care, results, and so forth, in order to maintain a balance of information. We have long since learned that perfection in technic alone does not make a surgeon. A knowledge of surgical physiology and other basic sciences is essential for good care.

The editor wishes to thank the various contributing authors for their splendid contributions and for their excellent cooperation. The most valuable suggestions made by numerous surgical friends are hereby acknowledged. The untiring effort of Miss Annabel Wheeler in the preparation of the text is likewise acknowledged. At all times the publishers have been most helpful and cooperative.

WARREN H. COLE

CONTENTS

Introduction

Doctor Cole's accomplishments as a general surgeon, now recognized throughout this and other countries, as well as his experience in contributing to surgical literature and in editing a textbook on general surgery, are a guarantee of the highest standards in a text on the operative technic in specialty surgery. Of the greatest importance is the choice of contributing authors in the specialities. In this, Doctor Cole has been most successful; he has chosen recognized leaders, well known for their skill as operating surgeons—surgeons who have had previous training in general surgery. This is especially evident in the chapters on the operative treatment of fractures, the neurosurgical procedures, and in the radical surgery for carcinoma in gynecological patients.

A serious fault of so many of the older books on operative surgery has been carefully avoided in this text. There are no discussions or illustrations of obsolete and discarded procedures that occupy so much space in many texts on operative surgery. Chosen for his known accomplishments and recent contributions to the technic of the various fields, each author gives in detailed fashion a clear description of the procedure he has found to be most effective for each lesion.

In the chapter on plastic surgery, I was most interested in the emphasis placed on the basic and sound principles of wound healing and tissue repair. It is a relief to see so much space devoted to immediate débridement and plastic repair of soft part wounds, especially of the face and hands, and so little space given to the repair of nasal deformities.

In the chapter on thoracic surgery, precautions and pitfalls relating to the various operative procedures are discussed in a clear and arresting fashion—an excellent addition to the detailed discussion of the steps and technics of the operations described.

The most recent advances that have been made in surgery have been in the field of cardiovascular operations. The indications for and the technics of these operations have been very largely determined by the younger generation of American surgeons and the desire for training with them has become increasingly evident in the last three or four years as shown in the number of foreign surgeons desiring graduate training in this field. Doctor Cole has been very wise and fortunate in his choice of men to discuss surgery of the heart and of the blood vessels. One of the very interesting developments in the last two or three years has been the use of plastic material which can be measured and cut and patterned for replacement in resected areas of arteries and veins. In fact, some surgeons at the present time use them in preference to preserved vascular grafts.

Few surgical treatises give so valuable and detailed information on operative procedures in the field of the locomotor and skeletal systems. Due consideration has been given to the increasing use of open operations in the treatment of fractures, with sound analysis of indications for these procedures and the technics to be used.

The material on neurosurgery, including the central nervous system,

the peripheral nerves and the autonomic nervous system, could be a monograph in itself for the contributors are well known authorities in these fields. Certainly it is evident after reading these sections that a thorough knowledge of neurology is as essential as experience in the technics of general and neurological surgery for anyone attempting this kind of operative work.

The radical surgery for cancer is gaining more recognition throughout this country. But equally well appreciated is the fact that those carrying out these very radical procedures must be surgeons with wide experience in general surgery. This is well illustrated in the radical procedures for carcinoma of the uterus—extensive *en masse* resection of the iliac and pelvic lymph nodes—and for women with localized spread to the bladder—a cystectomy with ureterosigmoidostomy. Gynecologists and urologists without general surgical training hesitate to transplant ureters into the colon and compromise with cutaneous ureterostomies, or incomplete resections of the bladder.

For one writing an introduction to this volume, the most interesting features are the choice of the contributors, the emphasis on the part of each to give in detail the procedure and technic for each lesion which, in his own experience, has given the best results and, finally, the evidence in many of the chapters of the importance of training and experience in general surgery before undertaking the surgery of the specialities.

Allen O. Whipple

OPERATIVE TECHNIC
IN
SPECIALTY SURGERY

1

THE BLOOD VESSELS

Michael E. DeBakey, Daniel Elkin, and Henry T. Bahnson

I. ACUTE VASCULAR INJURIES

Michael E. DeBakey

Acute or fresh injuries of major arteries, because they literally threaten both life and limb, have always constituted a serious problem in the surgical management of traumatic conditions. Obviously, and this has long been recognized, ideal therapy has as its objective preservation or restitution of vascular function, which is best accomplished by restoration of continuity of the artery at the earliest possible time. This desideratum can usually be achieved, although as has been pointed out previously(5), its attainment may not be possible for certain definite reasons. Essentially, these reasons may be divided into two categories: 1, those in which the factors are of such vital significance that they seal the fate of the part regardless of any form of therapy; and 2, those which jeopardize the effects of ideal therapy or preclude its institution. These factors are time lag, practical technical considerations, the presence of associated injuries, the site of injury, the type of arterial lesion, and the possible occurrence of infection.

The significance of the time lag, i.e., the time lapsing between wounding and institution of therapy, is obvious. This, however, is a relative, rather than an absolute, deterrent to a successful operation. Although no definite limit can be placed on the time lag beyond which success cannot be anticipated, the incidence of failure rises when repair cannot be undertaken *within the first 8 to 10 hours after injury*(13). The influence of the time lag varies because it is associated with a relative ischemia distant to the site of injury. The degree of ischemia is dependent upon the degree of disruption of the primary arterial channel, the collateral circulation, and the possible degree of collapse of the systemic circulation. Thus, in a patient with complete interruption of the popliteal artery and associated injuries which destroy the limited collateral pathways irreversible, ischemic changes will develop in the distant muscles much sooner than in a patient with a small laceration of the brachial artery which may permit some flow through the main artery or through a rich collateral system. The factor of associated injuries, whether they are local or remote, is also of considerable importance. Local wounds, depending upon their extent, may further impair or even completely destroy the regional circulation. More remote wounds may require attention far more urgently, as a lifesaving matter, than does the vascular wound.

Perhaps the most important factors determining end results are the site and type of the arterial lesion. Wounds of certain vessels, such as the pop-

liteal artery, are far more serious than wounds of other vessels, such as the brachial artery. Wounds above the profunda branch in both the femoral and brachial arteries are more likely to be followed by ischemic gangrene than wounds of these vessels below this branch. Accordingly, certain vessels have come to be regarded as critical and others as noncritical, and restorative surgical procedures obviously assume greater importance in the former category of vessels than in the latter. The type of injury (laceration of the vessel, partial or complete severance, contusion and thrombosis, acute spasm, or false aneurysm) also influences the outcome. A small, cleanly incised longitudinal wound, or even an incised transverse wound, may be repaired with greater chances of success than a lacerated wound in which there is much loss of substance.

In vascular injuries, therefore, the circumstances and character of the injury often determine the therapeutic procedure and consequently predetermine the end result. Under certain conditions the only procedure applicable is ligation, it must be done for the basic purpose of controlling hemorrhage. Under other conditions some type of reparative procedure may be employed, since this constitutes ideal therapy, every effort should be made to apply it.

SUPPLEMENTAL THERAPEUTIC MEASURES

All the established principles of good wound surgery, such as proper resuscitation of the patient and thorough débridement, are essential to the successful management of acute vascular injuries. These principles are discussed elsewhere and require no further elaboration here. There are, however, certain supplemental therapeutic measures that deserve consideration, including blood transfusion, sympathetic block or sympathectomy, anticoagulant therapy, and posture.

The extent of blood loss in acute vascular injuries is often considerable. As a consequence of the reduction in the volume of the circulating blood, the amount of blood flow through the peripheral arteries is also reduced, and the circulation of the part distal to the vascular injury is even further impaired. For these reasons, prompt restoration of the circulating blood volume and of the hemoglobin concentration assumes particular importance.

Vasospasm is a natural response to those forms of trauma which directly or indirectly affect vascular structures(4). Its extent and degree vary considerably. It may range from localized constriction, with consequent minimal ischemia, to a more extensive and generalized involvement, especially of the collateral circulation, with consequent ischemia of a degree sufficient to produce actual gangrene. Rational therapy in such cases is based upon an attempt to counteract vasospasm and to produce maximum vasodilatation in the involved extremity. Since the disturbance is apparently due to a vasomotor reflex initiated in the traumatized tissues, and since vasoconstrictor impulses are transmitted by way of the sympathetic nerve fibers, interruption of these impulses prevents vasospasm and permits vasodilatation. Vasodilatation may be achieved by débridement of surrounding traumatized tissue, by periarterial stripping of the involved area, by procaine hydrochloride block of the regional sympathetic ganglia, or by sympa-

thectomy. Sympathetic block or sympathectomy, which is probably the most effective method of producing maximum vasodilatation in these cases, should be employed in all types of peripheral vascular injuries accompanied by manifestations of vasospasm. It may be necessary to repeat the block at least once or twice daily for several days. Body warmth is carefully maintained but heat should *not* be applied to the involved part. As elevation of the part may accentuate ischemia, the extremity should be maintained at heart level, or preferably in a slightly dependent position. Immobilization of the extremity is probably unnecessary, although there may be occasional instances in which it will prove advisable. Because the arterial injury is usually associated with a contaminated soft tissue wound, antibiotic therapy should be used routinely.

On a theoretical basis, as well as on the basis of experimental and clinical investigations, the use of anticoagulants (heparin and dicoumarol) would appear to be a valuable adjunct in vascular surgery. By this means the extension of thrombosis in the peripheral collateral tributaries or the occurrence of thrombosis after operation at the site of repair, which so often spells failure, might be better controlled. It should be realized, however, that anticoagulant therapy is not without danger, especially in the presence of extensive injury. The method requires careful observation and adequate laboratory checks. Moreover, increasing clinical experience has shown that it is not essential to a successful result, provided an adequate technical reparative procedure has been done. Accordingly, anticoagulant therapy in vascular injuries is seldom indicated.

SURGICAL THERAPY

Ligation. In cases in which ligation is promptly indicated, as in wounds of the smaller noncritical vessels or because of the type and character of the injury, it should be done not by ligation in continuity but by placing nonabsorbable ligatures well above and below the site of injury, with excision of the intervening damaged segment in order to eliminate the dangers of secondary hemorrhage, thrombosis, and vasoconstrictor influences. Although it may be theoretically desirable to ligate at such a level as to avoid the creation of a blind pouch(10, 16), the deliberate effort to do so frequently involves extensive dissection and may still further jeopardize the circulation of the injured limb. If the concomitant vein is also injured, it should be similarly ligated; however, if undamaged it should *not* be disturbed.

Suture Repair. As has been indicated, the ideal objective in the therapy of vascular injuries is the restoration of the flow of blood through the original channel. This may be achieved, depending upon the character and extent of the injury, by suture repair, end-to-end anastomosis, or use of autogenous vein grafts or arterial homografts(3). The fundamental principles underlying all of these methods of vascular repair have long been well known. They have remained essentially unchanged, except possibly for certain refinements in suture material or in prosthetic devices, since the time of their establishment through the research efforts of numerous investigators, including, particularly, the work of Gluck(7), Jassinowsky(15), Murphy(21),

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jured vessel is exposed and isolated, provisional hemostasis is obtained by applying small rubber-shod spring artery clamps or preferably by non-crushing arterial clamps to the vessel above and below the site of the wound. An additional advantage of these special arterial clamps is that they permit the assistant to approximate the ends of the vessel during the anastomosis. All traumatized tissue and blood clots are removed, and ragged tissue and overhanging adventitia are excised, to provide clean smooth wound edges.

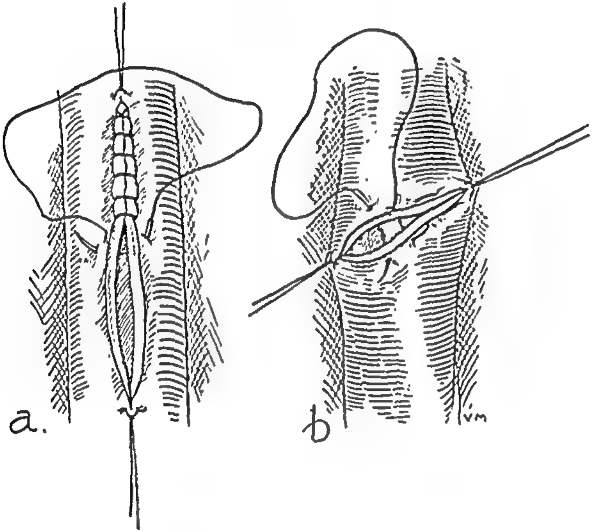

Fig. 1-1. Technic of suture repair of arterial wounds showing: a, continuous over-and-over type of suture, b, continuous mattress suture.

This should be done with considerable care and gentleness to minimize contusion or other injury to the endothelial edges of the wound. The cleansing of the wound and of the lumen of the vessel is facilitated by use of a stream of physiologic saline solution or of a 1:1,000 solution of heparin in physiologic saline solution. Periodic irrigation of the structures throughout the operation is also desirable, to prevent drying of the tissues. Traction or guy sutures are placed at each end of the wound, penetrating all layers of the vessels, to facilitate apposition of the endothelial surfaces and the performance of the suture repair (Fig. 1-1a). The suture material should be of fine silk (00000 or 000000) directly attached to a fine curved needle. This type of atraumatic

Jaboulay and Briau(12), Dorfler(6), Payr(22), Hopfner(9), Matas(17-19), Carrel and Guthrie(1, 2, 8), and Moure(20). The reader will find an excellent historical résumé of this phase of the subject in Matas' publications(17-19).

Suture repair of arterial injuries is particularly indicated in relatively small longitudinal or oblique wounds or in incomplete transections, especially of the larger arteries, such as the carotid, popliteal, common femoral, subclavian and axillary arteries. In complete or incomplete transections in which there is much loss of substance, end-to-end anastomosis should be done unless the defect is so great as to preclude approximation, and some means of bridging the defect must be employed.

Exposure must be adequate and should be achieved before a clot in the artery is dislodged. In order to accomplish this, the surgeon should make a longitudinal incision which will be designed to expose the artery proximal and distal to the point of injury. If a joint surface is involved, the incision should not be carried longitudinally across lines of flexion or extension, but whenever possible, should be altered by making an L or S shaped extension across the joint surface. The vessel should be exposed proximally and distally and an umbilical tape placed separately around the artery and the vein, both proximal and distal to the wound. This assures hemostasis, as the exposure is carried to the point of vascular injury. The artery should be clearly exposed and dissected from its underlying bed for several inches on each side of the point of injury, in order to permit the subsequent repair.

Once exposure and hemostasis are obtained, débridement of the soft tissues should be performed, for it is more difficult to débride the tissues beneath the artery once the repair has been performed. Débridement must be adequate, foreign bodies must be removed, and the wound must be throughly irrigated, for infection in inadequately débrided wounds may lead to secondary infection, thrombosis, and hemorrhage.

The injured artery itself must be adequately débrided, as intimal damage may lead to thrombosis immediately after surgery. Resection of the artery should include all grossly damaged areas. Histologic studies of the débrided artery have demonstrated that damage to the intima and damage to the underlying elastic membrane may extend a centimeter or more beyond the area which is grossly injured(14). Débridement of the segment of the artery which is grossly damaged will increase the length of the arterial defect, but is essential in the prevention of subsequent thrombosis(11).

The artery must be mobilized proximally and distally to a sufficient length to permit reapproximation of the artery without tension on the suture line. This may require division of arterial branches proximally and distally, which, although it reduces the collateral circulation, may often be essential to a successful repair.

Following débridement and mobilization of the artery, an effort should be made to approximate the cut ends of the vessel. If this cannot be accomplished without tension, an appropriate segment of the cephalic or saphenous vein should be obtained and used to bridge the arterial gap.

The essential principles of the suture method of vascular repair are: 1, provisional hemostasis; 2, the use of fine needles and silk; 3, accurate approximation of the intima; and 4, gentle handling of tissues. After the in-

be applied fairly closely (about 1 to 1.5 mm. apart) to prevent leakage between them. After the passage of each stitch, gentle traction is applied to the thread, so as to approximate the wound edges snugly, care being taken to provide intima-to-intima contact. The wound should be irrigated at fre-

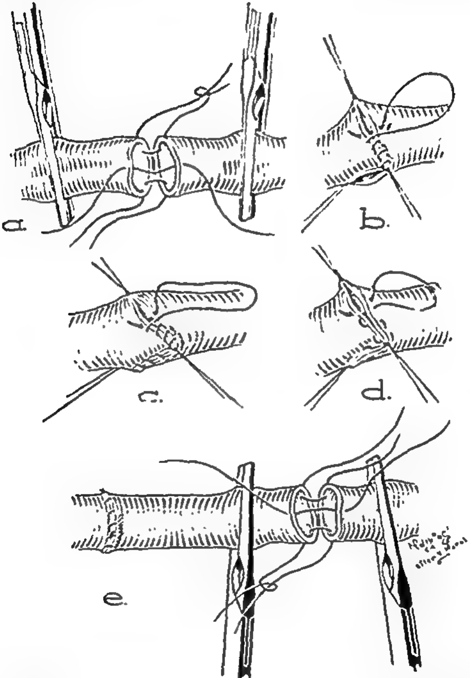

Fig. 1-2. Technic of end-to-end anastomosis of arteries by suture method showing: a placement of three stay or guy sutures at equidistant points of the circumference, b, traction upon guy sutures after they have been tied converts oval outline edges of vessels into straight triangular surfaces facilitating suture, c, each side of triangle is sutured consecutively by continuous over-and-over stitch, or d, by continuous mattress suture, e, anastomosis of graft, either autogenous vein graft or arterial homograft

quent intervals with saline. It is essential that throughout the operation, one assistant approximates the cut edges by means of the arterial clamps while another assistant tenses the guy sutures.

Following completion of the repair and removal of the hemostatic

arterial suture is available commercially in sealed tubes containing liquid petrolatum.

Various methods of applying the suture to approximate the wound edges have been employed, including single interrupted sutures, interrupted mattress sutures, a continuous over-and-over suture (Fig. 1-1a), or a continuous mattress suture (Fig. 1-1b). The continuous over-and-over stitch is the simplest and, in general, gives as good results as any of the others. The sutures should be applied fairly closely together (about 1 to 1.5 mm. apart), to prevent leakage between them. After the passage of each stitch gentle traction is applied to the thread, so as to approximate the wound edges snugly, care being taken to provide intima-to-intima contact. Following completion of the repair and removal of the hemostatic clamps above and below the artery, slight leakage at the suture line may be observed. Usually it will stop after the application of gentle pressure with moist gauze over the anastomosis. If this is not effective, it can be controlled with a reinforcing suture.

End-to-End Anastomosis. End-to-end anastomosis is indicated in wounds that incompletely or completely transect the vessel unless the loss of substance is so great (more than 3 cm.) that the resultant defect will not permit the ends of the vessel to be brought together without too much tension on the suture line. Under these circumstances, some means of bridging the gap, such as the use of autogenous vein grafts or arterial homografts(3), will be necessary. Several methods of end-to-end anastomosis have been employed, but the suture method is the most reliable and efficacious, all the others now being only of historic interest(17-19).

The principles of the suture method of end-to-end anastomosis, which is generally used today, are essentially those developed by Dorfler(6) and perfected by Carrel(1,2). Following exposure and isolation of the injured vessel, provisional hemostasis is obtained by the application of artery clamps to the artery above and below the site of injury. All traumatized tissue and blood clots are removed and the overhanging adventitia is excised and stripped away from the edges and the several ends of the vessel. Irrigation with saline solution or heparin and saline solution is employed, as previously described. The cut ends of the vessel are brought in apposition by the assistant holding the arterial clamps and two or three stay sutures are introduced through all layers of the vessel at equidistant points of the circumferences and are tied, care being taken to evert the edges to provide intimal apposition (Fig. 1-2a). By the application of gentle traction upon these stay sutures the oval outlines of the arterial ends are converted into straight triangular surfaces (Fig. 1-2b). The new contour facilitates apposition of the surfaces as well as eversion of the edges of the vessel, thus greatly simplifying the performance of suture anastomosis. Each side of the triangle is sutured consecutively, either by a continuous over-and-over stitch (Fig. 1-2b and c) or by a continuous mattress suture (Fig. 1-2d) as described above for lateral arteriorrhaphy, care being taken to provide apposition of the intima. As each segment of the angle is completed, it may be desirable to tie the running suture to the guy stitch. When the repair is completed anteriorly, the arterial clamps can be rotated, and one traction suture carried beneath the artery, so that exposure of the posterior surface can be obtained. The sutures should

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clamps above and below the artery, slight leakage of the suture line may be observed. Usually, it will of gentle pressure with moist gauze over the anastomosis. If this is not effective, it can be controlled with a reinforcing suture.

In cases in which the injury is associated with such extensive loss of substance as to preclude end-to-end anastomosis and in which arterial ligation does not seem promptly indicated, some method of bridging the gap is desirable in order to restore continuity of the artery. This is particularly true of injuries of critical arteries, such as the popliteal, common or internal carotid, common femoral, axillary, and brachial arteries. This may be accomplished by use of autogenous vein grafts (Fig. 1-2e) or preserved arterial homografts(3). In the vein graft method, a suitable segment of vein obtained from an accessible site is anastomosed to the proximal and distal ends of the artery by the suture method described above for end-to-end anastomosis. If vein grafts are used, it is desirable to employ a segment without valves, or, if valves are present, to place the vein between the ends of the artery with the valves facing distally. Another technical consideration is that the vein segment be of the exact length required to bridge the gap, to avoid either tension or kinking. Suitable segments of arterial homografts, preferably preserved by the freeze-dried method(3), may also be employed for this purpose.

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aneurysms do not tend to be as large as in the instances of arterial aneurysms since the decompression afforded by the vein relieves some of the tendency for expansion. Pathologically, the findings are those of two vessels encased in fibrous tissue. The false sac is similar to that previously described except that the tendency for a laminated clot to be present in the sac is less frequent. The wall of the sac is composed of fibrous tissue and contiguous structures. Its lining is that of flattened fibrous tissue. The artery and vein proximal to the fistula are enlarged. The vein distal to the fistula is enlarged but not so markedly as the proximal vein. The distal artery is diminished in size. Section studies of the vessel walls reveal no significant changes.

OPERATIVE TREATMENT OF ARTERIOVENOUS FISTULA

An arteriovenous fistula is usually the result of trauma but in rare instances may be congenital. The most common cause is a concomitant lateral wounding of an artery and vein which are closely positioned in a common sheath. The femoral and carotid vessels are ideally situated in this respect and are the ones most frequently involved. However, any vessels may be the site of the lesion and involvement of practically all the vessels of the body has been reported. In the presence of a fistula between an artery and vein, blood is short circuited from the artery directly to the vein. Depending upon the size of the fistula, its location and duration, certain effects upon the heart, the blood pressure and peripheral circulation take place. Following the establishment of a fistula, the heart dilates and the extent of the dilatation depends upon the duration of the fistula and the size of the opening. In large fistulas this dilatation takes place rapidly and eventually results in cardiac failure. The effects upon the heart, the general circulation and the part affected demand that the fistula be eliminated. Prior to operation, a period of bed rest should be carried out, particularly if there is any heart involvement. If actual heart failure is present, preliminary digitalization should be accomplished. The patient's general condition, including his nutrition, should be brought to the highest point. All infection, particularly in the region of the operative site, should be cleared for a period of at least a month.

The time interval between injury and operation is important. In general, the operation should be performed as early as possible after collateral circulation has been established. This, as a rule, will require two or three months and by that time the wound causing the lesion usually will be healed and the danger of infection will have passed. Moreover, in rare instances, small fistulas may heal spontaneously within that time.

Blood donors should be available for every operation and in some instances blood should be ready for transfusion before the operation is begun. The operation should be carried out with greatest care because of the large number of collateral vessels which are usually encountered and because their thinness and friability make them particularly liable to injury which may lead to serious hemorrhage. Bleeding from the smaller collateral vessels may be readily controlled by coagulation. Others should be ligated with fine, nonabsorbable ligatures, and in vessels of any size, ligatures should be reinforced by transfixion sutures.

II. TRAUMATIC ANEURYSM AND ARTERIO-VENOUS FISTULA

Daniel Elkin

The wounding of blood vessels results in a progression of changes and varied clinical phenomena which are largely dependent upon the extent of injury to the vessel wall. Traumatization of the arterial wall by passage of a missile near it or from forceful displacement of the vessel may result in no external evidence of damage; rupture of the intima may occur, with thrombosis and sympathetic disturbances, as manifest by a cold pulseless extremity. Extensive injury to the vessels produces a similar deprivation of arterial supply to the extremity with the additional obstruction of the remaining collateral channels by the tension resulting from a hematoma. Bleeding, both external and into the surrounding tissues, with the anemia which results, is also a factor in determining the viability of an extremity. Partial injuries to vessel walls are frequently manifest by similar changes or after a period of several weeks or months, by the development of an arterial aneurysm or an arteriovenous fistula.

Partial division of the arterial wall will result in the formation of a hematoma. The size of the hematoma will depend upon the elasticity of the surrounding structures, the ease with which the blood may escape through an external wound and the extent and type of arterial damage. This hematoma will at first pulsate; as clotting occurs a progressively diminishing area in which unclotted blood is in free exchange with the artery results. Organization of the clot by fibrous tissue progresses with the formation of an ovoid mass. This aneurysmal wall is composed of fibrous tissue and is supported by surrounding structures. The innermost layer of fibroblasts becomes flattened and resembles endothelial cells. The characteristic layers of a true arterial wall are absent. A clot, laminated in nature, forms within the aneurysmal sac, and it also constantly undergoes organization with a tendency toward spontaneous cure of the aneurysm. Unfortunately, this is rarely attained and rupture of the sac is frequent with expansion of the aneurysm. The deposition of calcium in the wall of the sac is occasionally found on roentgenologic examination.

If concomitant wounds of the artery and vein occur an arteriovenous fistula may result. Lateral wounding of the artery and vein, either by a missile which passes between the two vessels or which passes through both vessels with the lateral wounds becoming sealed, may result in a direct shunt of blood from the artery to the vein. An excellent anastomosis of artery and vein may be produced by trauma with little external bleeding particularly if the injured vessels are held in close apposition by a common sheath. In such an instance there is little scar tissue formation. As the vessels enlarge as a result of the fistula, the opening of communication may similarly enlarge. Frequently a false aneurysm is found in association with the arteriovenous connection, the aneurysm may lie between the vein and artery, or may project from a site of injury to either vessel. These false

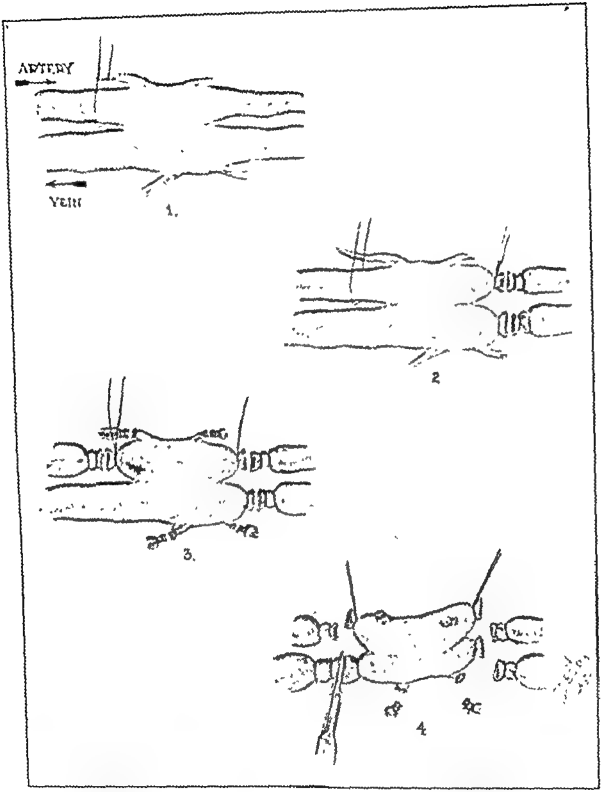

Fig 1-3 The four steps in ligation and excision of an arteriovenous fistula: 1, A suture is passed around the proximal artery, 2, The distal vessels are ligated and divided, 3, The proximal artery and the communicating vessels are ligated and divided, 4, The proximal vein is ligated and divided as the last step in the procedure (From Elkin South M J, 39 311, 1946.)

If the position of the lesion permits, a tourniquet, preferably of the inflatable type, is placed above the operative site but is not inflated unless severe hemorrhage is encountered. Where possible, the skin incision should be made along anatomic lines and care should be taken not to cross skin folds transversely. No matter what type of operation is carried out, the artery proximal to the lesion should first be isolated and a ligature passed around it for control of possible hemorrhage. Ligation of the artery proximal to the fistula alone may temporarily eliminate the bruit and thrill so characteristic of the lesion, but it will not cure the fistula and may lead to gangrene. Likewise, ligation of the four major branches, that is, the proximal and distal arteries and veins may temporarily eliminate the bruit and thrill but will not cure the fistula, since it will readily be reestablished through its collaterals and communicating branches.

In the treatment of arteriovenous fistulas, one of two procedures is most generally employed: first, some type of operation whereby the communication between the artery and vein is obliterated by sutures; or, second, ligation of the vessels leading to and from the fistula and its complete extirpation. It is preferable where possible to preserve the continuity of the artery. This is frequently impossible because the vessels at the site of the lesion are so embedded in scar tissue as to prevent accurate dissection of the communication. Moreover, the opening may be so large that its closure necessitates occlusion of the vessel. Likewise, the presence of a false sac directly communicating with the artery or vein, or transposed between the two vessels, may prevent proper closure with the maintenance of the arterial lumen.

It must be borne in mind that while operative repair is ideal in preserving the continuity of the artery, it is not without danger. Secondary hemorrhage, thrombosis, and recurrence are more apt to follow this procedure than complete excision of the fistula.

Arterial repairs in which scar tissue is utilized may be followed by a false arterial aneurysm.

The operations most frequently performed for this condition are:

A. Quadruple ligation and division of the main vessels, and excision.
B. Repair of the arterial opening after removal of a portion of the vein.
C. Transvenous closure of the opening.
D. Repair of the opening in both artery and vein.
E. Mass ligature of the fistula where A, B, C or D cannot be carried out.

A. Quadruple Ligation of the Main Vessels, and Excision. Step 1. The artery proximal to the fistula is isolated and a ligature passed around it. This ligature is placed for safety should severe hemorrhage be encountered, but is not tied at this time since occlusion of the vessel would interfere with pulsation of the vessels distal to the fistula and make their isolation more difficult as well as obscuring the exact site of the fistula (Fig. 1-3, step 1).

Step 2. The main artery and vein distal to the fistula are isolated, doubly ligated, transfixed and divided (Fig. 1-3, step 2).

Step 3. The artery proximal to the fistula about which a ligature was previously placed is doubly ligated, transfixed and divided. All vessels communicating with the fistula, except for the proximal vein, are then ligated and divided and the fistula is lifted from its bed (Fig. 1-3, step 3).

expose the communication which is then closed transvenously by interrupted sutures of fine silk. Here too, if the closure results in obliteration of the artery, it should be excised. The adherent vein may be used to reinforce the suture line (Fig. 1-5).

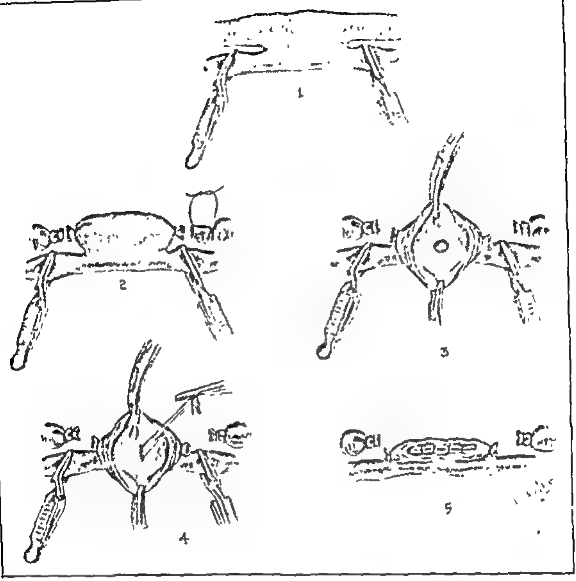

Fig. 1-5. Steps generally employed in the transvenous or trans-saccular repair of an arteriovenous fistula with preservation of the artery. (From Elkin, Surg., Gynec. & Obst., 82-5, 1946.)

D. Repair of the Opening in Both Artery and Vein. This procedure is the most difficult to carry out. The proximal and distal artery and vein are exposed and occluded by vessel clamps as in C. Communicating vessels are ligated and divided. If there is a minimum of scar tissue and if the communication is small, the vessels may be separated, thus exposing the arterial and venous openings which are closed as in B and the clamps removed.

E. Mass Ligature of the Fistula. On rare occasions it may be impossible, particularly in the presence of severe hemorrhage, properly to isolate the vessels as described above. Here it may be necessary to obliterate the fistula by a series of mass ligatures. Such a method is undesirable, since

STEP 4. The vein proximal to the fistula is ligated and divided and the fistula is removed. Ligation of the proximal vein is reserved as the last step of the operation in order to provide a passageway for emptying the blood from the fistula. The numerous tributaries demand a careful and painstaking dissection of all vessels in order that the field be kept as free from blood as possible throughout the procedure (Fig. 1-3, step 4).

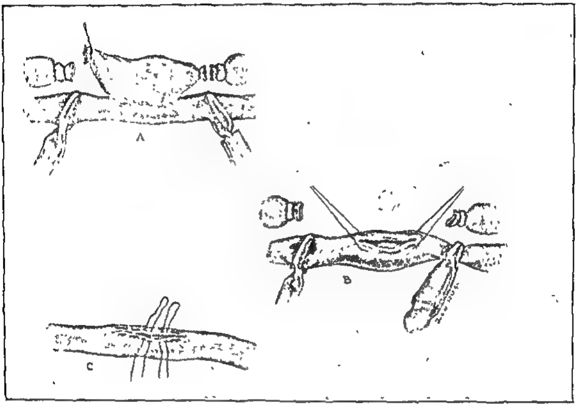

Fig. 1-4 Repair of an arteriovenous fistula. The arterial opening is closed with sutures after removing a portion of the vein (From Elkin South. M J., 39:311, 1946.)

B. Repair of the Arterial Opening after Removal of a Portion of the Vein. The artery, proximal and distal to the fistula, is exposed and isolated and arterial clamps are applied on either side of the lesion. The vein proximal and distal to the fistula is exposed and ligated and divided on either side (Fig. 1-4A). All communicating vessels are isolated and divided. A portion of the vein is then carefully dissected away from the artery and discarded, thus exposing the arterial opening. The edges of this opening are usually freshened and then closed by interrupted mattress sutures of fine silk, being careful in the first row to approximate intima-to-intima (Fig. 1-4B, C). Further reinforcing sutures are placed in the adventitia. The clamps are removed and any leaking point is further reinforced. The placing of surrounding muscles directly over the opening will act as a further hemostatic agent. *If the carrying out of this procedure results in occlusion of the vessel, that portion should be excised.*

C. Transvenous Closure. Exposure of the proximal and distal arteries and veins, followed by ligation and division of the vein, is carried out as in B. Clamps are then applied to the artery above and below the fistula. The vein is ligated and divided proximal and distal to the fistula and opened to

still have a place (Fig. 1-6). In 1888, Matas described his method of intrasaccular suture of the vessels feeding the aneurysm, which he named endoaneurysmorrhaphy. Later Brasdor and Wardrop independently ligated the artery or one of its principal branches on the distal side of the sac in an attempt to slow the circulation through it and thus encourage its clotting. All these methods with the exception of the Matas procedure were frequently followed by infection, hemorrhage, gangrene, or failure to cure the condition. Of them, only the Matas operation has stood the test of time and it is now performed in essentially the same way as that described by its originator.

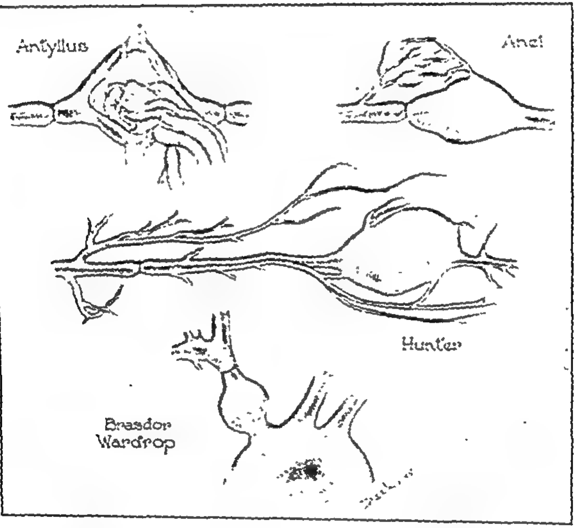

Fig 1-6. Diagrammatic illustration of the types of operation employed for the treatment of aneurysms prior to the introduction of endoaneurysmorrhaphy (From Elkin. Surg., Gynec & Obst, 82 4, 1946.)

Matas Endoaneurysmorrhaphy. If the position of the aneurysm permits, blood is emptied from the extremity by elevation, the application of a pressure bandage and finally by application of a tourniquet, preferably of the inflatable variety. The operation may then be performed in a bloodless field. If the application of a tourniquet is precluded by the position of the aneurysm, temporary occlusion of the proximal vessel by the application of an arterial clamp is of aid in performing the operation in a less bloody field. The aneurysmal sac is then opened, taking care to avoid any nerves which

adjacent structures, particularly nerves, may be injured and recurrence and secondary hemorrhage are likely to follow.

In any operation upon blood vessels, the most scrupulous attention should be paid to asepsis. Infection of any severity may be followed by secondary hemorrhage. Since this lesion is usually the result of an external wound, the presence of a latent infection should not be overlooked and the postoperative use of penicillin as a prophylactic measure is advised until such time as any evidence of infection has passed.

After operation, if there is a considerable degree of cardiac dilatation, or if there is actual clinical evidence of cardiac failure, bed rest, proper medication and a slow return to work are indicated.

Sympathetic interruption as a means of increasing the circulation is usually not indicated nor necessary in an arteriovenous fistula because of the collateral circulation which develops as a result of the lesion. However, should claudication and evidence of ischemia develop after operation, this procedure should be given serious consideration.

OPERATIVE TREATMENT OF ARTERIAL ANEURYSMS

An aneurysm is the result of trauma or of disease. In the latter, the usual predisposing causes are syphilis and arteriosclerosis which cause the vessel to give way with a resulting fusiform swelling (a true aneurysm), or to rupture into surrounding tissues with the formation of a pulsating sac, the walls of which are formed by fibrous tissue and surrounding structures. A third type, usually the result of arteriosclerosis, is a dissecting aneurysm in which blood escapes from the lumen of the vessel and dissects between the layers of the artery (usually the aorta) for a variable distance.

Regardless of the cause, those aneurysms amenable to operative treatment may be considered together as the principles underlying this treatment are the same. In general, it consists of 1, measures designed to produce a clot in the aneurysmal sac or to induce the formation of fibrous tissue about it and thus prevent further expansion and rupture; 2, obliteration of the sac by closure of the offending vessel; or 3, extirpation of the aneurysm-bearing portion of the artery.

A variety of methods, many of them unsuccessful, are to be found in the recorded annals of surgical treatment. Compression by various methods (digital, bandaging, instrumental) and the introduction of sclerosing and coagulating agents have been employed. Older operative methods included that of Antyllus (second century A.D.) which consisted of ligation of the vessel above and below the sac, the evacuation of its contents and the application of an astringent or of packing. Anel's operation (1710) consisted of ligation of the proximal artery close to the sac. This may still be used, but ischemia, recurrence and even gangrene are likely to follow. Later, John Hunter tied the femoral artery in the canal which bears his name, for aneurysm of the popliteal artery. It was Hunter's idea to bring about clotting and eventual cure and at the same time preserve collateral circulation, a definite improvement on Anel's procedure. In this he was highly successful, except for the frequent recurrence which took place through the circulation he was so anxious to preserve. On occasion, these methods

still have a place (Fig. 1-6). In 1888, Matas described his method of intrasaccular suture of the vessels feeding the aneurysm, which he named endoaneurysmorrhaphy. Later Brasdor and Wardrop independently ligated the artery or one of its principal branches on the distal side of the sac in an attempt to slow the circulation through it and thus encourage its clotting. All these methods with the exception of the Matas procedure were frequently followed by infection, hemorrhage, gangrene, or failure to cure the condition. Of them, only the Matas operation has stood the test of time and it is now performed in essentially the same way as that described by its originator.

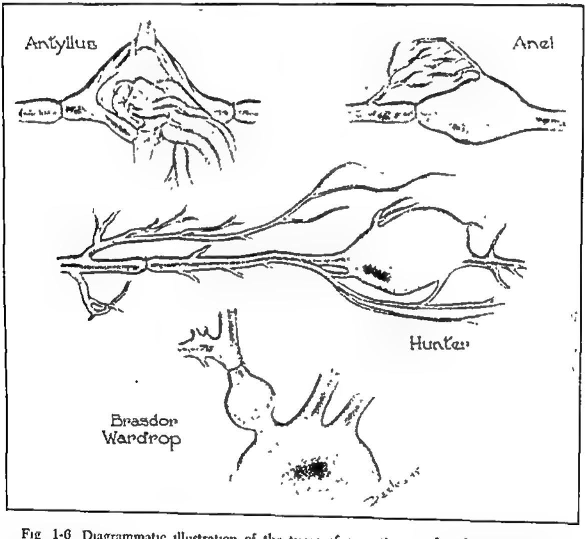

Fig 1-6 Diagrammatic illustration of the types of operation employed for the treatment of aneurysms prior to the introduction of endoaneurysmorrhaphy. (From Elkin, Surg., Gynec. & Obst, 82.4, 1946.)

Matas Endoaneurysmorrhaphy. If the position of the aneurysm permits, blood is emptied from the extremity by elevation, the application of a pressure bandage and finally by application of a tourniquet, preferably of the *inflatable* variety. The operation may then be performed in a bloodless field. If the application of a tourniquet is precluded by the position of the aneurysm, temporary occlusion of the proximal vessel by the application of an arterial clamp is of aid in performing the operation in a less bloody field. The aneurysmal sac is then opened, taking care to avoid any nerves which

may be stretched over it. The clot is evacuated and search is made for the openings in the artery. If not readily found, temporary loosening of the tourniquet will disclose their position. Usually one or two figure-of-eight sutures of silk are sufficient to close the openings (Fig. 1-7). If bleeding occurs after removal of the tourniquet, these can be reinforced by the placing of other sutures. Matas advocated obliteration of the sac by further suturing, but this is difficult because of its friable nature. In some instances the proximal and distal vessels can be dissected from surrounding structures *within the sac* and individually ligated. Closure of the skin and subcutaneous tissues with the application of a snug elastic bandage will bring about obliteration of the sac.

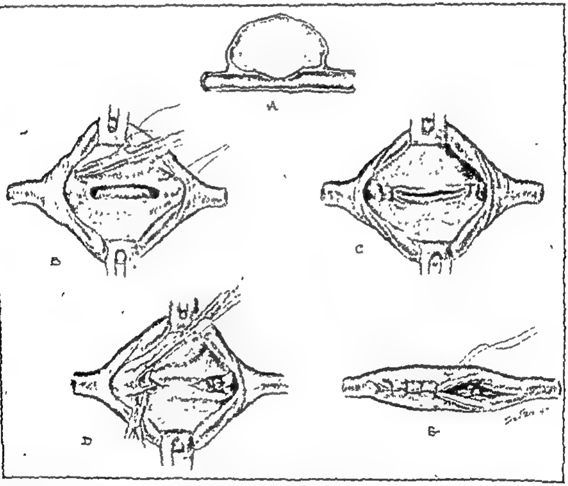

Fig 1-7. Diagrammatic illustration of endoaneurysmorrhaphy. A, cross section of artery with false sac. B, sutures are placed to close the arterial openings within the sac. C, sutures tied D, occasionally the vessel is isolated and ligated. E, occasionally the sac is obliterated by further sutures (From Elkin, Surg., Gynec. & Obst., 82:6, 1946.)

Excision of Aneurysm. Associated injuries to structures other than the blood vessel frequently make it desirable to remove the sac. This is particularly true if nerve injuries are to be repaired or if a bone graft is contemplated. Following suitable preoperative measures to enhance the circulation, such as proximal intermittent compression of the artery, and suitable tests to insure the adequacy of the collateral circulation, the aneurysm may in many instances be excised with safety.

An incision is made over the course of the vessels involved regardless of

the most prominent point of presentation of the aneurysm. The artery is isolated proximal to the false sac with preservation of all branches possible. The artery distal to the aneurysm is similarly ligated and divided. As the sac is approached the artery is doubly ligated, transfixed, and divided. Dissection may then be continued distally with ligation of all entering vessels as they are encountered and with final complete removal of the aneurysm. Care must be taken to prevent injury to any nerves which may lie upon or be in close relation with the sac as it is dissected free.

Proximal Arterial Ligation. Aneurysms in certain locations, namely those in which there are few arterial branches, occasionally respond favorably to proximal ligation alone. This procedure is frequently performed for intracranial aneurysms, aneurysms of the carotid arteries, iliac arteries, and the aorta. Ligation with division is the procedure of choice if the competency of the collateral circulation will permit but frequently a partial occlusion must be done as an initial stage to complete occlusion in elderly patients.

Measures to Produce Clotting or Increase Fibrous Tissue Formation. Aneurysms of the aorta are usually not amenable to treatment by any of the methods described. Success has been reported in their treatment by the insertion of a coil of wire into the enlarged vessel and the stimulation of clotting by heating the wire with an electric current.

Large aortic aneurysms which are producing pain or in which rupture is imminent are benefited by extensive mobilization of the vessel with the application of cellophane about the lesion. In this procedure a double purpose is served. Fibrous tissue formation is stimulated with reinforcement of the aneurysmal wall; the sympathetic nerves to the vessel are interrupted with subsequent decrease in pain.

ANESTHESIA

Fractional spinal anesthesia is preferred for operation upon the lower extremities, since the procedures are usually long and tedious. For operations elsewhere in the body intravenous pentothal sodium, nitrous oxide, and oxygen is the anesthetic of choice. In operations on the neck, the introduction of an intratracheal tube insures an open airway and a smoother anesthetic.

III. ANEURYSM OF THE AORTA

Henry T. Bahnson

Established methods in the treatment of aneurysms of peripheral vessels only recently have been advocated and practiced for aneurysms of the aorta. Endoaneurysmorrhaphy, ligation, and excision have occasionally been employed in the past, but operative risk has been great and few survivals have been reported. In recent years and with the great progress in cardiovascular surgery, instruments for and technics of operations upon the aorta have been developed, so that now direct attack upon aortic aneurysms is associated with less risk and greater likelihood of cure than formerly.

Aortic aneurysms are almost invariably caused by either syphilis or arteriosclerosis. Occasional aneurysms are congenital or caused by trauma or bacterial infection, but in most respects these uncommon aneurysms resemble those due to syphilis. Arteriosclerotic and syphilitic aneurysms differ strikingly in their clinical characteristics (Fig. 1-8). Syphilitic aneurysms are usually saccular and occur in younger patients. They almost always arise above the renal arteries, predominantly on the ascending aorta and the aortic arch. They frequently produce symptoms, often from erosion of bone and from pressure upon adjacent nerves or vital structures in the neck and thorax. Syphilitic aneurysms are associated with a poor prognosis; a review of 633 patients by Kampmeier showed that only 18 lived longer than two years. The average duration of life from the onset of symptoms to death in all except these 18 patients was between six and nine months.

Arteriosclerotic aneurysms, on the other hand, occur in the terminal aorta, almost always below the origin of the renal arteries. They occur in older patients, predominantly males, are fusiform in nature and usually do not produce striking symptoms or signs. Pain is the most frequent complaint but still is present in only about half the patients seen with this condition. Pain may be severe enough to require the use of narcotics or to be associated with loss of weight. It is usually an ill defined pain in the abdomen, sometimes in the back or down the legs. It is not usually related to posture or to activity.

The prognosis for patients with an arteriosclerotic aneurysm is better than that for patients with a syphilitic aneurysm. Estes(6) has reported a follow-up of 102 patients with abdominal aneurysm, all but two of whom had arteriosclerosis as a major cause of the aneurysm. From his data one can estimate that in one patient out of five seen with an abdominal arteriosclerotic aneurysm the aneurysm will rupture within a year, and half the patients will die of rupture within eight years.

Methods of Treatment. Of the methods used in the treatment of peripheral aneurysms which are listed in the section on traumatic aneurysms (page 10) only intrasaccular wiring and an effort to increase fibrosis about the aneurysm have been used to any extent in recent years. The wiring technic has been most refined by Blakemore(3), who inserts a fine, insulated silver wire which, after it is introduced, can be heated to cause concentric

clotting. Twenty-seven per cent of Blakemore's patients were living 10 years after wiring. These results are good when compared with those following other methods which were then used, but they are not ideal.

So called cellophane wrapping has been widely employed, and there are numerous single case reports of successful use of this material to induce fibrosis and clotting in the aneurysm. The active ingredient in the film which induces fibrosis has been identified by Yeager and Cowley(9) as dicetyl phosphate. Means of applying this chemical in high concentrations about the aneurysm have been developed(2). Even with this refinement, it seems to the writer that although fibrosis can be produced, subsequent scar contracture is unlikely unless thrombosis in the aneurysm occurs as a result of operative trauma. In a series of 32 patients treated by wrapping reported by Abbott there was no prolongation of life in any with advanced disease, and the only benefit claimed was relief of pain in 40 per cent.

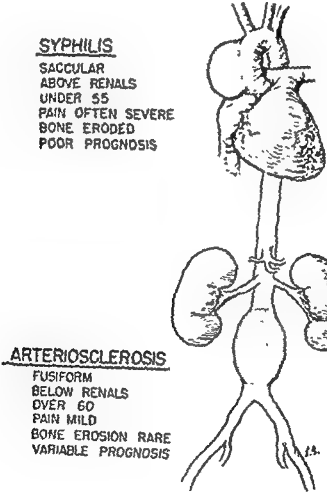

Fig. 1-8. Frequent but not invariable clinical characteristics of the two commonest types of aortic aneurysm. (From Bahnson, H. T. Ann. Surg., 138:377, 1953.)

Excision of an aortic aneurysm appears to be the ideal treatment when it can be performed. Recent experiences have shown that excision is feasible in all areas of the aorta and that most syphilitic and arteriosclerotic aneurysms can be so treated(1, 4). Syphilitic aneurysms can be excised [illegible] they frequently result from a localized rupture and have a relatively [illegible] mouth. The mouth of the aneurysm can be occluded [illegible]

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artery. Sometimes the superior vena cava is obstructed and sufficient contrast material cannot be introduced to allow visualization of the aorta and the aneurysm. In such instances the technic of Peirce(8) has been used by which a small polyethylene catheter is inserted percutaneously into a femoral artery and advanced retrograde into the aneurysm. In the majority of instances the catheter, which cannot be directed and simply follows the contour of the aorta, will enter the ascending aorta or the aneurysm itself (Fig. 1-9). Advancement of the catheter, which is filled with contrast material, is observed under the fluoroscope. Care must be exercised that the injection of contrast material, usually 15 to 20 ml. of urokon or diodrast, is not made at the region of the carotid and left common carotid arteries. Injection directly into the carotid arteries may cause convulsions and has caused death. Visualization of the mouth of the aneurysm so obtained is helpful in planning operative exposure. Frequently in instances where the aneurysm is near the surface, as when erosion has occurred through the ribs or sternum, a direct injection of the aneurysm itself may be performed. Unless the blood-containing lumen is extremely close to the skin, there is little danger from this procedure.

Contrast visualization of an arteriosclerotic aneurysm in the terminal aorta is helpful principally to demonstrate the extent of the aneurysm. In almost all instances the aneurysm will be located below the renal arteries. Two patients have been encountered, however, in whom the aneurysm extended to or above the level of the renal arteries. In one of these syphilis played a large part in causing the aneurysm. This fact should be ascertained before operation as occlusion of the renal flow is associated with a somewhat increased risk to the patient. Similarly it is helpful to determine the lower limits of the aneurysm in order to select the proper type of homograft for replacement. Translumbar aortography with injection of contrast material through a long needle directly into the aorta has been satisfactory for this visualization. Patients are usually anesthetized with pentothal and nitrous oxide, although the procedure may be carried out with local infiltration.

THORACIC ANEURYSM

After the aneurysm and its mouth are localized as well as possible, the type of operative exposure may be more accurately planned. For an aneurysm about the ascending aorta and proximal portion of the aortic arch, the commonest site for syphilitic aneurysms, splitting the sternum with an incision extending into one or both pleural cavities has been most helpful. For those on the ascending aorta, incision of the right anterior fourth interspace, the sternum being split in the midline, is ideal (Fig. 1-10). For an aneurysm in the region of the left common carotid artery and the distal portion of the aortic arch, incision through the left second interspace and vertically split sternum has been satisfactory (Fig. 1-11). In some instances this incision needs to be carried across the midline into the right second interspace. With adequate control of ventilation by an intratracheal tube one need have little fear of entering both pleural cavities, although postoperative discomfort and morbidity are probably increased. For an aneurysm distal to the aortic arch, a posterolateral incision gives satisfactory exposure.

some instances the aorta itself may be temporarily occluded and the aorta reconstructed from aneurysmal wall. Arteriosclerotic aneurysms are in a favorable position because of their almost constant localization to the aorta distal to the origin of the renal arteries. In this position the aorta may be occluded while the aneurysm is excised and a homograft inserted. Although in both types there is generalized and widespread arterial disease, derangement is most conspicuous in the area of the aneurysm. When this lesion is excised the remaining cardiovascular system may be functionally adequate for many years.

Fig. 1-9. Demonstration of aneurysm on the ascending aorta by contrast material. The polyethylene catheter was inserted through a Robb angiocardiographic needle in the femoral artery and advanced retrograde into the aneurysm. During this procedure the catheter, being filled with contrast material, can be observed fluoroscopically.

Aortography. In addition to the usual methods of evaluation of these patients for major surgery it is helpful to obtain contrast visualization of the aneurysm. In the case of an upper thoracic aneurysm this may be impossible because of difficulties of roentgen visualization in this region. Of the several means of visualization, angiocardiography is frequently of greatest help, for, in addition to demonstrating the aneurysm itself, it frequently will show obstruction or pressure upon the great veins and the pulmonary

sharp dissection. Damage to bronchi and trachea, innominate veins and vena cava must be avoided. One innominate vein may usually be divided if necessary to mobilize the aneurysm; division of both innominate veins or the vena cava should be avoided. Usually, if the surgeon concentrates on mobilizing the aorta and great vessels *in areas slightly removed from* the aneurysm, dissection is easier and can then be continued toward the aneurysm. In some instances the operator must dispense with caution and dissect boldly as, for example, by passing a finger between the ascending aorta and

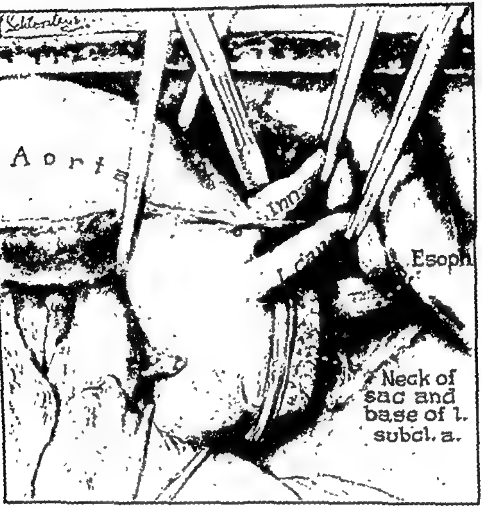


Fig 1-11 Exposure of aneurysm of midportion of aortic arch through left anterior second interspace and split sternum The base of the aneurysm and its origin from the aorta are usually free and can be dissected for placement of the occluding instrument Coarctation clamp used to occlude mouth of the aneurysm in this instance. (From Bahnson, H. T. Ann. Surg., 138.377, 1953)

the right bronchus for an aneurysm of the innominate artery. Before such boldness is exhibited, however, all possible less dangerous dissection must be completed, as in this instance mobilization of the aorta proximal to the innominate artery and of the subclavian and common carotid arteries. A thorough knowledge of thoracic, and especially mediastinal, anatomy is indispensable.

In the early experiences various instruments were used to occlude the mouth of the aneurysm. The Potts multitoothed principle was found to be most useful. In addition it is helpful to have an instrument which can be

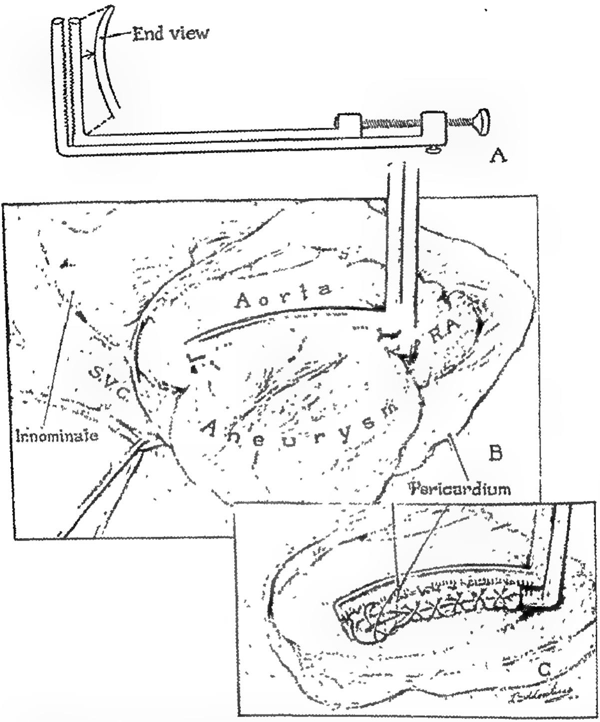
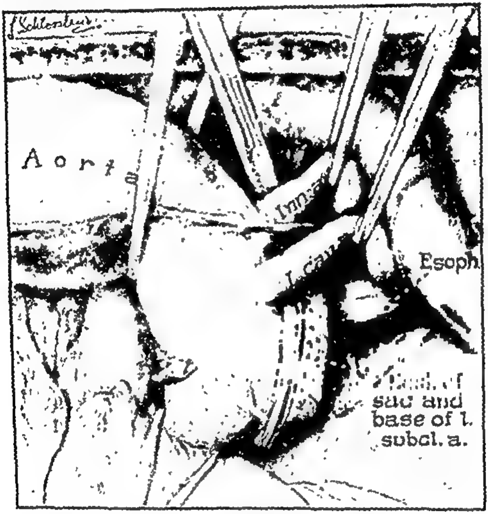


Fig. 1-10 Excision of aneurysm on the ascending aorta. Exposure is through the right fourth interspace, the sternum being split in the midline Aneurysms here are almost always inside the pericardium which facilitates mobilization of the mouth of the aneurysm. A special instrument is used to occlude the mouth of the aneurysm

In all instances the aorta proximal and distal to the vessels arising from the aneurysm or from the aorta in the region of the aneurysm must be isolated before an effort is made to mobilize the aneurysm itself. In most instances the aneurysm is adherent to the adjacent structures and mobilization of the aneurysm itself is difficult, however, the part of the aorta from whence the aneurysm arises frequently has few surrounding inflammatory adhesions, and the mouth of the aneurysm may be isolated by blunt and

sharp dissection. Damage to bronchi and trachea, innominate veins and vena cava must be avoided. One innominate vein may usually be divided if necessary to mobilize the aneurysm; division of both innominate veins or the vena cava should be avoided. Usually, if the surgeon concentrates on mobilizing the aorta and great vessels in areas slightly removed from the aneurysm, dissection is easier and can then be continued toward the aneurysm. In some instances the operator must dispense with caution and dissect boldly as, for example, by passing a finger between the ascending aorta and



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In the early experiences various instruments were used to occlude the mouth of the aneurysm. The Potts multitoothed principle was found to be most useful. In addition it is helpful to have an instrument which can be

tightened to a uniform degree throughout the extent of its occlusion regardless of the thickness of the mouth of the aneurysm; this has required the construction of a sliding type of instrument as shown in Figure 1-10.

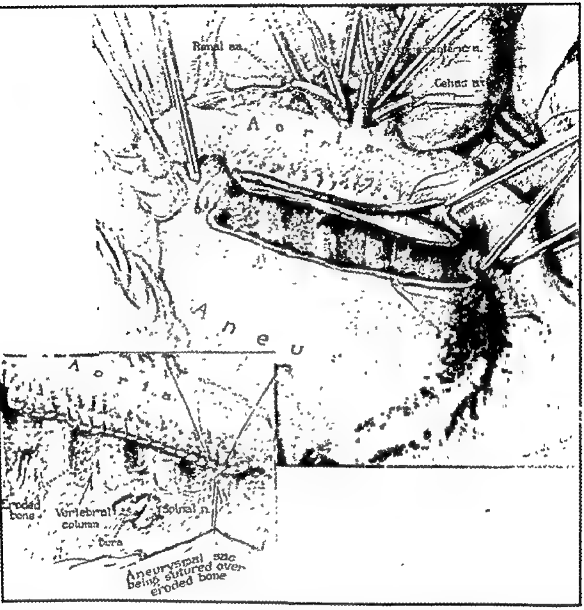

Fig. 1-12 Exposure of aneurysm of upper abdominal aorta through bed of tenth rib and abdominal extension. Mouth of the aneurysm was directly behind the visceral branches. Branches and aorta are occluded and aneurysm incised. A portion of the mouth of the aneurysm is saved as a cuff to use for closure. Mouth of the aneurysm closed with a layer of mattress and an additional layer of figure-of-eight sutures of fine silk. (From Bahnson, H. T. Surg., Gynec. and Obst., 96: 382, 1953.)

When the mouth of an aneurysm on the ascending aorta is occluded, and actually when manipulation of the aneurysm is performed, it is advisable to occlude temporarily the innominate and left common carotid arteries. This occlusion should be for short periods of no more than a minute, repeated when needed. In one instance clot has been dislodged from the rim of the aneurysm and has passed into the cerebral circulation.

Once the mouth of the aneurysm is occluded the aneurysm may be entered and incised throughout its circumference, a cuff of tissue being pre-

served for suturing. The opening has been closed by numerous fine silk sutures, an interrupted mattress layer being placed nearest to the occluding clamp and a row of figure-of-eight sutures placed over the cut edge. Several additional sutures are frequently required after removal of the occluding clamp. After the opening in the aorta has been sutured, the aneurysmal sac and contained clot can be excised. Excision of the aneurysmal sac is an important step as several instances have been reported in which the sac became infected and caused the death of the patient. However, except for removal of clot to gain space, removal of the sac should usually be delayed until the aorta has been sutured.

The aorta may be occluded for progressively longer periods if the occlusion is done at progressively greater distances from the heart. In one instance the aorta was occluded between the innominate and the left common carotid artery for seven minutes before hypotension and cardiac arrythmia occurred. This was sufficient time to allow opening of the aneurysmal sac and suturing of a slitlike mouth of the aneurysm in a patient with a lesion which resulted from trauma. It is doubtful whether the mouth of a syphilitic aneurysm would be sufficiently small to allow adequate treatment in so short a time. The thoracic aorta may be occluded for a considerably longer period. The principal danger is one of damage to the spinal cord which might result in paraplegia. Crafoord(5) has occluded the aorta in many patients during treatment of a patent ductus arteriosis, but in some instances there was demonstrable evidence of damage to the spinal cord.

Aneurysms in the thoracic aorta may be treated by either excision and insertion of a homograft or reconstruction of the aorta from the adjacent normal aorta and a small cuff of aneurysmal sac. When a homograft is employed, the use of a temporary shunt may be helpful. Making openings in the adjacent aorta for insertion of plastic tubes does not seem wise to this writer, but a tube may be placed inside the graft, temporarily tied in place, and removed just before completion of the final suture. Polyethylene or methacrylate tubes are satisfactory for this purpose. Aneurysms in the upper abdominal aorta must be treated by incision and reconstruction from the remaining aorta, because of the visceral branches which arise in this region (Fig. 1-12).

ABDOMINAL ANEURYSM

Arteriosclerotic aneurysm of the terminal abdominal aorta is a somewhat different problem. The aorta may be occluded for a much longer period in this region (up to two and a half hours in some patients successfully treated by the author). During this period of aortic occlusion the aneurysm may be excised and a homograft inserted. Dissection about the aneurysm, especially posteriorly and between the aneurysm and the inferior vena cava, can be most easily performed after the aorta has been divided and the aneurysm drawn forward (Fig. 1-13). Lumbar veins become readily apparent under these circumstances and may generally be avoided. Care must be exercised in dissection around the inferior vena cava, and if small tears or openings appear they must be carefully sutured with arterial silk rather than grasped with a hemostat; such clamping is apt to tear the thin caval wall. Aneurysmal dilatation frequently stops at the bifurcation of the aorta or

bifurcation of the common iliac arteries, and anastomosis can be made to the distal vessel. In some instances placques are present at the site of anastomosis. These may be excised and anastomosis made to the remaining media and adventitia. Almost invariably a satisfactory artery may be obtained if one excises sufficient length of vessel, in some instances out to the external iliac arteries. The hypogastric arteries may be ligated with safety. The inferior mesenteric artery is usually thrombosed but may be ligated if patent.

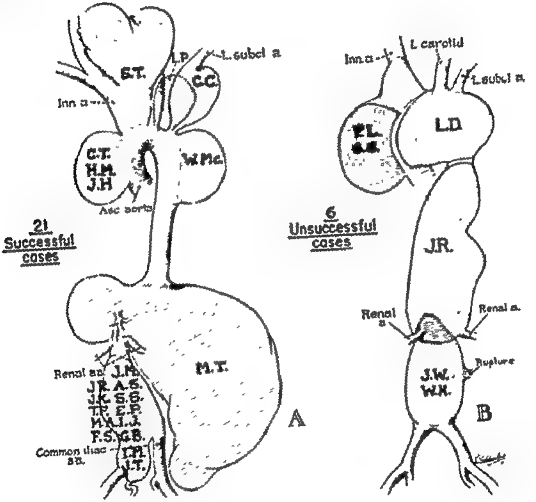

Fig 1-13 Illustration of types of aneurysm and results obtained up to August, 1953.

An extremely important step is the instillation of heparin into the distal iliac artery when the aorta and the iliac arteries are occluded. If this is not done a thrombus may form from the site of the occlusion to the entrance of the next major collateral artery, and when the aorta is reopened this clot will be washed distally, resulting in ischemia of the leg. This has happened in three of our patients, all of whom required amputation.

Results of treatment of aortic aneurysm in 17 months ending August 1953 are shown in Figure 1-13. All surviving patients with syphilitic and traumatic aneurysms are well and essentially symptom free. Of the patients with arteriosclerotic aneurysm of the terminal aorta, the single patient who had been submitted to endoaneurysmorrhaphy continues to have pain. This

operation is just as difficult as excision and homografting and, judging from a small group of patients operated upon by Kirklin(7), offers less chance of cure. It is no longer employed by the author. Of the other patients with aneurysm of the terminal aorta two have died of acute coronary infarction and myocardial failure. These two patients and one additional one have required amputation, as stated above, for ischemic necrosis, presumably from dislodgement of clot into the distal circulation. Remaining patients in this group are well and have resumed activities commensurate with their age.

Excision of the aneurysm and reconstruction of the aorta from adjacent tissue or reconstruction by homograft appear to the author to be the best treatment at present available. Sometimes, however, particularly with aneurysm about the aortic arch, the lesion cannot be excised with survival of the patient. In such instances the use of wire as described by Blakemore(3) should be considered.

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IV. SURGICAL TREATMENT OF ANEURYSMS AND OCCLUSIVE DISEASE OF THE ABDOMINAL AORTA

Michael E. DeBakey

The segment of abdominal aorta between the renal arteries and the bifurcation is a relatively common site for the occurrence of two serious diseases, namely, aneurysm and occlusive disease (also termed Leriche's syndrome or insidious thrombosis of the aortic bifurcation)(2, 10, 12, 13). The underlying process in most cases is arteriosclerosis with progressive weakening and dilatation of the aortic wall on the one hand or progressive narrowing and intimal changes leading to thrombosis and complete occlusion of the lumen on the other. As a consequence, both conditions are associated with increasingly disabling symptoms and eventually with lethal complications, resulting in the case of aneurysm from pressure or rupture and in the case of thrombo-obliterative disease from progressive arterial insufficiency, ischemia, and gangrene.

Until relatively recent years the various methods of therapy which have been used for these conditions have not been satisfactory and may be considered palliative at best. For aneurysmal disease they have been directed essentially toward promotion of thrombosis and fibrotic organization by various means, including particularly partial, complete, or gradual occlusion or ligation of the aorta, introduction of foreign material, or use of fibroplastic agents. For occlusive disease, lumbar sympathectomy and thrombo-endarterectomy have been generally advocated but neither has yielded entirely satisfactory results(2, 10, 12, 13, 15). Because of the increasing dissatisfaction with these methods of therapy and because of the grave prognosis of these lesions during the past few years, efforts have been directed toward a more effective form of therapy. This consists essentially in resection of the involved segment of aorta and restoration of function by means of an aortic homograft(1, 3, 5-9, 11, 14). Although technically, performance of this procedure is much the same for both aneurysms and occlusive disease of the aorta, certain features in each instance deserve separate consideration.

ANEURYSM

Characteristically, most aneurysms of the abdominal aorta are fusiform in type, arteriosclerotic in origin, and located in the segment of abdominal aorta between the renal arteries and the bifurcation. Moreover, they usually arise sufficiently below the origin of the renal arteries to provide an adequate margin of relatively normal aorta to permit application of the occluding clamp without interruption of renal blood flow. These characteristic pathologic features have certain fortunate surgical implications. For one thing, temporary arrest of the circulation at this low aortic level, for the time required to perform the procedure, averaging about one to one and one-half hours, is associated with little or no danger of ischemic damage

to the kidneys, spinal cord, or other vital organs. For another, there is usually sufficient margin of relatively normal aorta immediately below the origin of the renal arteries to permit anastomosis to the graft. Indeed, up to the present writing in a series of 128 cases in which exploration was performed, only one has been encountered that proved to be inoperable because the aneurysm extended well above the renal arteries. Distal extension of the aneurysm has been found to be an even less limiting factor to resection. To be sure, the majority of cases involve the bifurcation, but sufficient lengths of relatively normal common iliac arteries are usually available to permit anastomosis to the graft. In some instances, however, these vessels are too extensively involved in the aneurysmal process for this purpose, and it becomes necessary to anastomose the graft to both the external and internal iliac arteries. Less commonly, it may be necessary to sacrifice the internal iliac arteries because of extension of the aneurysmal process and consequently to perform the anastomosis of the graft to the external iliac arteries alone.

As most of these aneurysms are arteriosclerotic in origin, they usually show varying degrees of atheromatous changes and roentgenologic evidence of calcification. Indeed, in many instances the aorta, as well as the aneurysm, may be readily visualized in plain roentgenograms of the abdomen by the interrupted peripheral outline produced by the process of calcification. Fortunately, this has not proved to be a serious limiting factor, and the anastomotic procedure has been found to be technically feasible in all cases in spite of rather extensive atheromatous changes in some.

Clinically, few contraindications to operation have been encountered. Most of these patients are in the older age group and therefore liable to the systemic degenerative changes of the aged. But age in itself is not a contraindication to operation in the face of urgent reasons, such as rapid progression of the aneurysm or imminent or actual rupture. This is exemplified by the fact that the procedure was successfully performed in a patient 79 years of age. Hypertension in itself is likewise not a contraindication to operation, as evidenced by the fact that approximately one fourth of the patients in our series had moderate to severe hypertension. The most important potential contraindications to operation are serious cardiac and renal disease. In the face of such disturbances, the procedure is probably inadvisable unless there is a pressing reason, such as an immediate threat to the patient's life from rupture of the aneurysm.

Technical Considerations. A transperitoneal approach through a midline incision extending well above and below the umbilicus is preferred and provides adequate exposure to this segment of the aorta (Fig. 1-14a). The small intestine with its mesentery is retracted to the right, and the posterior peritoneal layer overlying the aneurysm along with the ligament of Treitz is divided to permit mobilization of the duodenum to the right (Fig. 1-14b). In performing the latter procedure, the surgeon should be extremely careful to avoid injury to the duodenum, which is often intimately adherent to the aneurysm. At this stage of the procedure it is desirable to expose, by careful sharp and blunt dissection, the aorta immediately above the aneurysm and just below the origin of the renal arteries in order to encircle it with umbilical tape as a safety measure for control of hemorrhage from possible

accidental perforation of the aneurysm during subsequent dissection. It should be recalled that the left renal vein lies anteriorly over the aorta in this region, and care must be taken to prevent its injury during this dissection The inferior mesenteric artery is then divided between suture ligatures as closely to its origin as possible, to allow further lateral mobilization

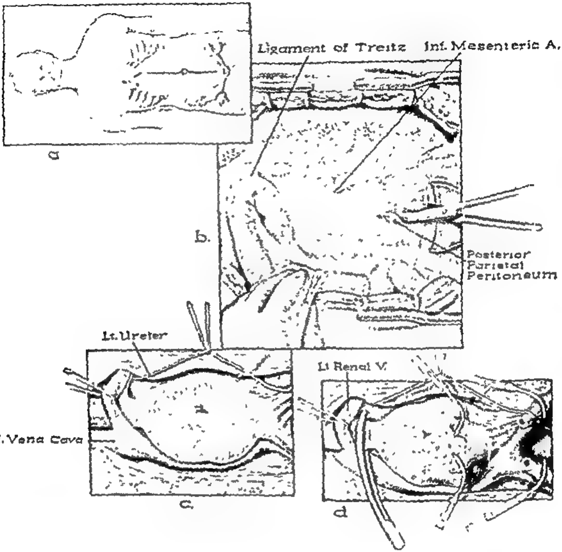

Fig 1-14 Drawing showing technic of resection of aneurysm of abdominal aorta and replacement by homograft. a, a midline incision is used to enter the peritoneal cavity. b, the small intestine along with its mesentery is retracted to the right and the posterior peritoneal layer overlying the aneurysm and the ligament of Treitz are divided to permit mobilization of the duodenum and exposure of the aneurysm c, the inferior mesenteric artery is divided between ligatures to permit further lateral mobilization of the mesentery, and care is taken to identify and free the ureters to avoid their injury d, occluding clamps are applied across the aorta above the aneurysm but below the renal vessels and across both common iliac arteries below the bifurcation Excision of the aneurysm is then done by dividing the iliac vessels and freeing the aneurysmal wall from its attachments posteriorly and to the vena cava

of the mesentery of the descending colon and sigmoid and better exposure of the iliac vessels below. Efforts are then directed toward mobilization of the iliac arteries below to permit their encirclement with umbilical tape. This dissection also requires considerable care in order to avoid injury to the underlying iliac veins, which are often intimately adherent to these arteries. Once the aorta above and the iliac arteries below are encircled with

umbilical tape, attention is directed toward further mobilization and separation of the aneurysm from its surrounding structures, particularly along its lateral and posterior lateral walls (Figs. 1-14c and 15). In the performance of this dissection, the surgeon should exercise particular care to avoid injury to the vena cava on the right and the ureter on the left, as these structures are often intimately adherent to the wall of the aneurysm. Under these circumstances, it is often desirable to delay further separation of these structures until after occluding clamps have been applied to the aorta above and the iliac arteries below the aneurysm.

Fig 1-15. Photograph taken at operation showing aneurysm of abdominal aorta which has been sufficiently freed from surrounding structures to permit application of occluding clamps immediately prior to excision. Umbilical tapes encircle both iliac arteries below and the aorta immediately above the aneurysm and just below the overlying left renal vein. Immediately beneath the tip of the hemostat is an area of intimate adherence of the aneurysm to the vena cava

Before the occluding clamps are applied, however, and in order to minimize the time during which the aortic circulation is temporarily arrested, the aortic homograft should be prepared for immediate use. This includes reconstitution of freeze-dried homografts, which should be started as soon as it is determined that the aneurysm is resectable, since this may require from one-half to one hour of immersion in physiologic saline solution(4). Following this procedure, all small branches arising from the graft, such as the lumbar arteries, must be ligated, preferably with fine silk. The graft may

accidental perforation of the aneurysm during subsequent dissection. It should be recalled that the left renal vein lies anteriorly over the aorta in this region, and care must be taken to prevent its injury during this dissection. The inferior mesenteric artery is then divided between suture ligatures as closely to its origin as possible, to allow further lateral mobilization

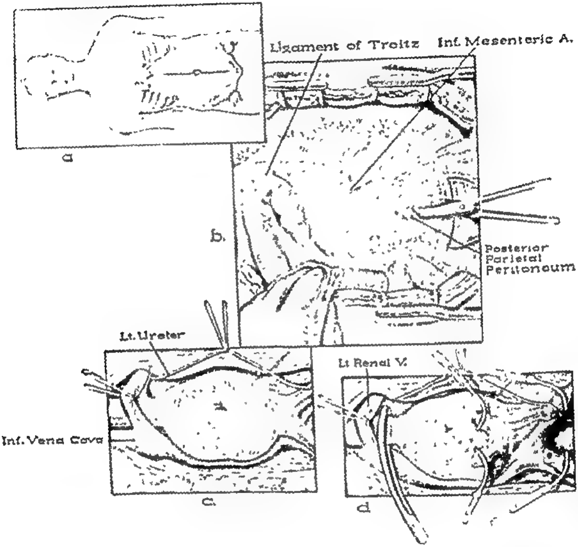

Fig 1-14 Drawing showing technic of resection of aneurysm of abdominal aorta and replacement by homograft a, a midline incision is used to enter the peritoneal cavity. b, the small intestine along with its mesentery is retracted to the right and the posterior peritoneal layer overlying the aneurysm and the ligament of Treitz are divided to permit mobilization of the duodenum and exposure of the aneurysm c, the inferior mesenteric artery is divided between ligatures to permit further lateral mobilization of the mesentery, and care is taken to identify and free the ureters to avoid their injury d, occluding clamps are applied across the aorta above the aneurysm but below the renal vessels and across both common iliac arteries below the bifurcation Excision of the aneurysm is then done by dividing the iliac vessels and freeing the aneurysmal wall from its attachments posteriorly and to the vena cava

of the mesentery of the descending colon and sigmoid and better exposure of the iliac vessels below. Efforts are then directed toward mobilization of the iliac arteries below to permit their encirclement with umbilical tape. This dissection also requires considerable care in order to avoid injury to the underlying iliac veins, which are often intimately adherent to these arteries. Once the aorta above and the iliac arteries below are encircled with

1-16c, d, e, f). The distal anastomosis is performed in a similar manner. In the case of a bifurcation homograft, the anastomosis is similarly performed to one of the iliac arteries, using No. 00000 arterial silk. Before this distal anastomosis is attempted, the graft must be more accurately tailored

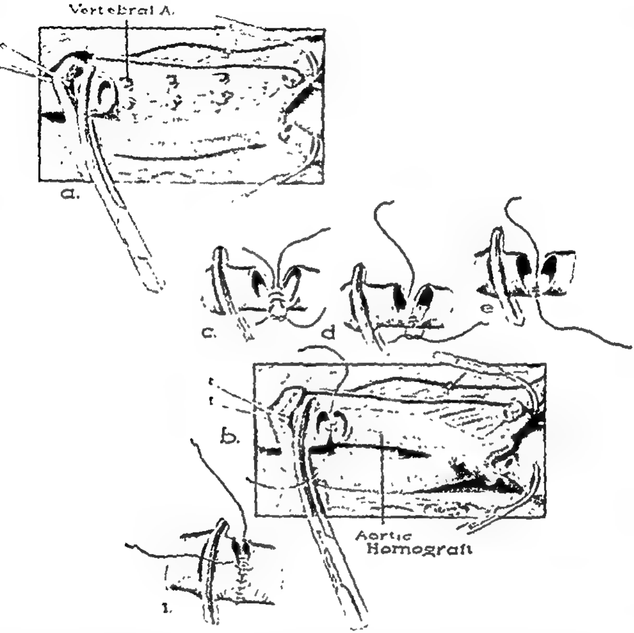

Fig. 1-16. Continuation of procedure described in Figure 1-14. a, the diseased segment of aorta including the aneurysm between the occluding clamps has been excised and the defect can now be bridged with an aortic homograft. b, the proximal anastomosis of the graft is performed first using two lengths of sutures, each of which is anchored at the most posterior point of the aortic circumference as shown in c, d, and e. One of these sutures is then brought forward as a through-and-through suture to approximate the ends of the graft and the aorta for one-half the circumference, following which the other is similarly applied to approximate the opposite side as shown in 1. The two sutures are then tied to complete the anastomosis.

by placing it on slight tension and trimming the distal segment to approximate the corresponding vessel of the patient. In the case of a bifurcation homograft, after one of the iliac anastomoses has been completed, it is desirable to allow blood flow through the graft during performance of the osite iliac anastomosis. This may be accomplished by applying an oc-

then be tested for other small openings by injecting saline solution into it by means of an asepto syringe having a long glass nozzle which may be threaded snugly into one end of the graft while the other is occluded. Obviously, much operative time may be saved if the graft is prepared by an assistant team during the previously described steps in the operation.

Excision of the aneurysm constitutes the next step in the operation. A long handled, atraumatic arterial clamp is applied to the aorta above, but prior to complete occlusion of the aorta with this clamp, 10 mg. of heparin solution is injected into the aneurysm. The purpose of this procedure is to combat the possible thrombophilic effect of the retarded blood flow in the distal vascular bed. Within a few seconds after completion of this injection, the aorta above is completely occluded, and similar clamps are then applied to the iliac arteries below. The aneurysm may then be excised between these clamps. In cases in which the bifurcation is involved, it is usually preferable to begin below by dividing the iliac arteries and freeing the posterior wall of these structures and the bifurcation from the underlying iliac veins and vena cava (Fig. 1-14d). As this dissection is continued upward, precautions must be taken to avoid injury to these thin-walled structures, which may be intimately adherent to the right lateral and posterior lateral wall of the aneurysm. Under these circumstances, it is often possible to separate these structures by intramural dissection of the aneurysmal wall in this adherent region and leave a thin layer of the adventitial wall of the aneurysm attached to the vena cava. In such cases, the ostia of the lumbar arteries presenting in this remaining posterior wall of the aneurysm are oversewn, but if the entire posterior wall can be readily separated, the lumbar vessels may be individually clamped and ligated. Division of the aorta immediately above the aneurysm, leaving a sufficient margin below the occluding clamp to perform the anastomosis to the graft, completes the resection (Fig. 1-16a).

The excised segment of aorta is then replaced by the previously prepared aortic homograft, which, of course, includes the bifurcation and iliac arteries when these structures have been excised along with the aneurysm. If it has not been necessary to resect the bifurcation along with the aneurysm, it is preferable to employ a homograft of the descending thoracic aorta because its slightly larger caliber provides better approximation. In most cases the diameters of the aorta above and the iliac arteries below will be found to be slightly greater than those of these respective vessels in the graft. In general, this discrepancy may be readily overcome by slight beveling of the anastomotic ends of the graft

Preferably, the proximal anastomosis of the graft to the aorta is performed first. A simple continuous through-and-through suture of No. 0000 arterial silk is considered most desirable for the anastomosis and has been found to facilitate the procedure in the presence of atheromatous changes in the aortic wall. Performance of the anastomosis is also facilitated by using two lengths of suture, first anchoring each at the most posterior point of the aortic circumference (Fig. 1-16b) One of these sutures is then used to approximate the ends of the graft and the aorta for one half of the circumference, the other suture being similarly applied to approximate the opposite side; tying the two sutures completes the anastomosis (Fig.

Fig. 1-18. Photograph taken at operation following completion of anastomosis of homograft and restoration of normal blood flow through it.

THROMBO-OBLITERATIVE DISEASE

Like most aneurysms of the abdominal aorta, thrombo-obliterative disease of the aorta apparently develops on the basis of an arteriosclerotic process which seems to begin most frequently in the iliac arteries at or near the bifurcation with atheromatous plaques and calcified ulcerated areas in the intima leading to thrombus formation(2, 10, 12, 13). These changes cause progressive stenosis of the lumen with ultimately complete occlusion. Gross and histologic studies of excised specimens suggest that once complete occlusion occurs at the bifurcation level, there is a tendency for gradual propagation of the thrombotic process upward as high as and occasionally above the renal arteries(8). Mural changes in the aorta at this upper level are often relatively minimal, the lumen simply being occluded by a thrombotic process in various stages of organization. At the bifurcation level, however, the mural degenerative changes are usually extensive and involve both intima and media. Thus, whereas the occlusive thrombotic process may be readily peeled away from the upper portion of this segment of aorta, leaving a relatively normal and functionally useful aortic wall, in the lower portion about the bifurcation the wall is usually too extensively destroyed for this purpose. Moreover, these degenerative mural changes often do not extend downward much beyond the bifurcation of the common

cluding clamp to the remaining iliac segment of the graft and releasing the other occluding clamps on the opposite iliac artery and the aorta (Fig. 1-17a). The aortic occluding clamp should be slowly released to avoid a sudden drop in blood pressure. Leaking from suture holes is usually controlled by application of gauze sponges and slight pressure. Occasionally, it may be necessary to reinforce a bleeding point at the line of anastomosis with an additional suture.

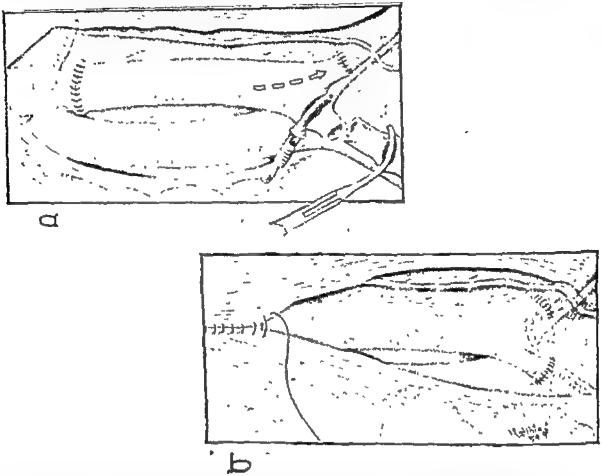

Fig. 1-17. a, after the proximal anastomosis and one of the iliac anastomoses has been completed, it is desirable to allow blood flow through the graft during the performance of the opposite iliac anastomosis. This is accomplished by applying an occluding clamp to the remaining iliac segment of the graft and releasing the other occluding clamps on the aorta and the opposite iliac artery. b, after completion of the anastomosis of the graft, the edges of the posterior peritoneal layer and ligament of Treitz are approximated over the aorta and homograft.

Following completion of the anastomosis and restoration of blood flow through the graft, bilateral lumbar sympathectomy may be performed (Fig. 1-18). This is particularly advisable in patients with preoperative evidence of arterial insufficiency in the lower extremities or if the period of aortic occlusion has been necessarily prolonged, more than 90 minutes for example. Clinical experience suggests that there is some type of vasospastic response in the peripheral arterial bed in the lower extremities to prolonged aortic occlusion. The operative procedure is completed by approximating the ligament of Treitz and posterior peritoneal margins overlying the aorta and homograft and by closure of the abdominal wound (Fig. 1-17b).

systolic murmur in the abdomen near the umbilicus. These latter findings constitute important differential signs in distinguishing this type of occlusive process from the more peripheral form of arteriosclerosis obliterans. Thus, whereas in the latter type of peripheral vascular disease somewhat

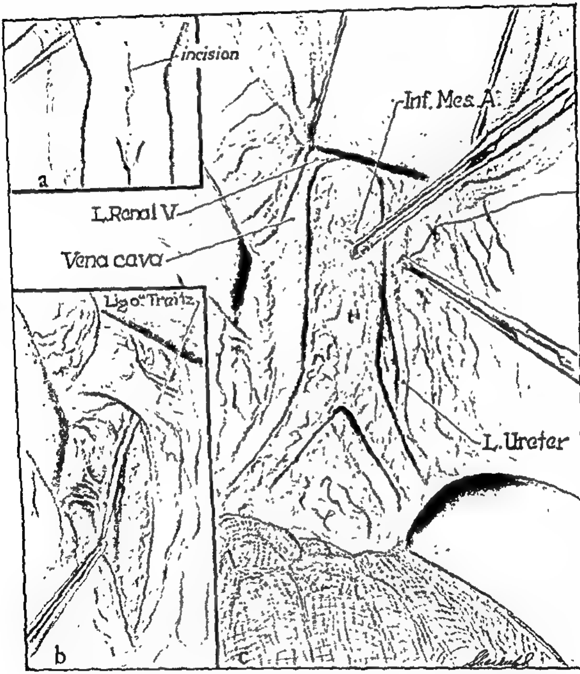

Fig 1-20 Drawing showing operative technic of resection of thrombo-obliterative disease of abdominal aorta with restoration of continuity by aortic homograft a, the peritoneal cavity is entered through a midline incision. b, after mobilizing the small intestine and its mesentery to the right, the aorta is exposed by linear division of the overlying posterior parietal peritoneum and ligament of Treitz. c, the inferior mesenteric artery is clamped, divided and ligated near its origin and the aorta freed from its surrounding structures.

similar manifestations of arterial insufficiency may be present in the lower extremities with absence of pedal pulsation, the femoral pulses are usually palpable and a systolic murmur in the abdomen is not heard.

The most important diagnostic procedure, however, is aortography, since

iliac arteries. Indeed, it is frequently possible to utilize the common iliac arteries immediately above their bifurcation, following removal of the intimal proliferative layer along with the superimposed thrombotic process by thrombo-endarterectomy. Thus, the relatively segmental and fairly well delimited pathologic destructive process in this disease lends itself well to treatment by excision and repair with homograft replacement.

Fig 1-19. Aortogram of patient with clinical manifestations of thrombo-obliterative disease of aorta showing complete occlusion of terminal portion of aorta just above the bifurcation with patency of femoral arteries below

Clinically, the disease is characterized by insidious and slowly progressive development, with symptoms of intermittent claudication, pain, and easy fatigability, particularly in the hips and thighs posterolaterally, and sexual impotency. Physical signs include not only the usual manifestations of arterial insufficiency but also, and of particular significance, absence of pulsations in the femoral arteries, as well as in the pedal vessels, and a

systolic murmur in the abdomen near the umbilicus. These latter findings constitute important differential signs in distinguishing this type of occlusive process from the more peripheral form of arteriosclerosis obliterans. Thus, whereas in the latter type of peripheral vascular disease somewhat

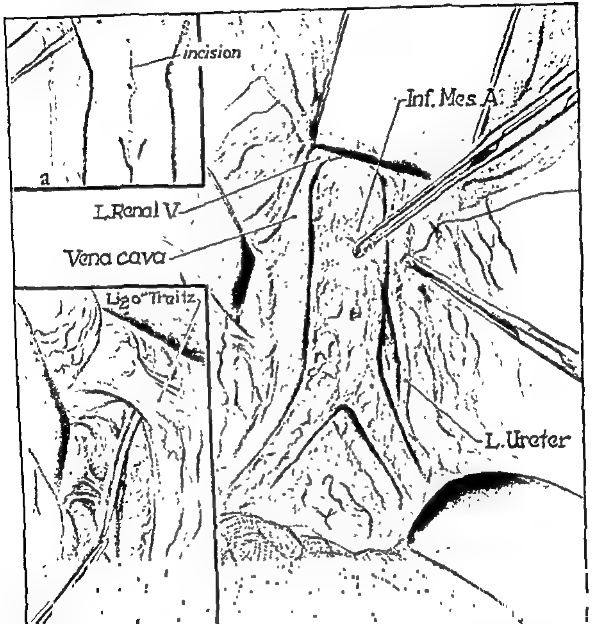

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Fig. 1-19 Aortogram of patient with clinical manifestations of thrombo-obliterative disease of aorta showing complete occlusion of terminal portion of aorta just above the bifurcation with patency of femoral arteries below.

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about the aortic bifurcation and another in the femoral artery in the thigh, usually in the region of Hunter's canal. Under these circumstances, excisional therapy with homograft replacement may be done for both lesions

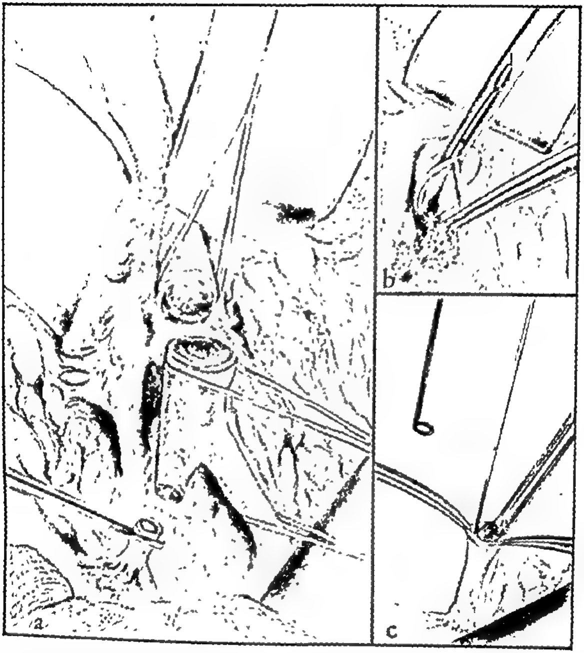

Fig 1-22 (Continued from Fig. 1-21) a, the aorta has been transected at a point where it is completely occluded by the thrombotic process and the right iliac artery has been similarly divided b, after applying an occluding clamp to the aorta above the occlusive process, the partially organized thrombus is peeled away from its mural attachment to this segment of aorta c, a wire loop stripper, similar in design to a Mayo vein stripper, is used to remove the intraluminal occlusive process in the distal segment of the iliac arteries

Technical Considerations. Except for certain technical details, the operative procedure for thrombo-obliterative disease is essentially similar, particularly as regards exposure and anastomosis, to that described for aneurysm of the abdominal aorta. A transperitoneal approach through a midline incision is employed, and the aorta is exposed by linear division of the posterior parietal peritoneum along with the ligament of Treitz (Fig. 1-20a, b).

this clearly demonstrates the occlusive process in the terminal portion of the aorta (Fig. 1-19). By this means too, luminal patency of the distal portion of the iliac or femoral arteries may be demonstrated. The segmental nature of the occlusive process is thus visualized, providing evidence of operability.

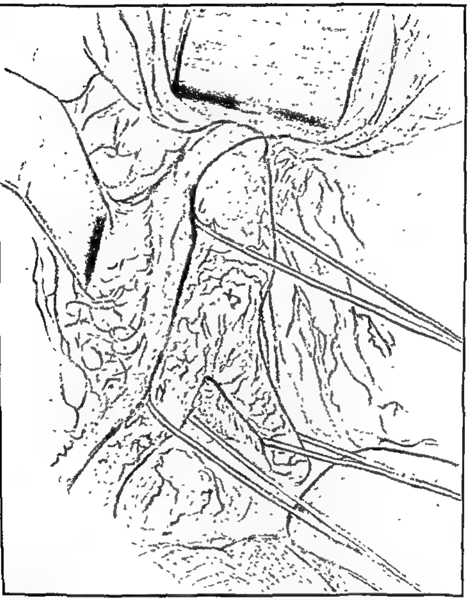

Fig. 1-21 (Continued from Fig 1-20) Circumferential mobilization of the aorta just below the overlying left renal vein and of the iliac arteries permits encirclement with umbilical tape.

Most of these patients are in the fourth to sixth decades of life. Being therefore somewhat younger than those with aneurysms, they are less likely to have serious cardiac and renal disturbances and are consequently better surgical risks. Proper preparation for operation, however, includes careful evaluation of these and other vital functions. Aside from any serious disorder of this kind, the chief contraindication to operation is evidence, usually by means of arteriography, that the arteriosclerotic occlusive process is not segmental but diffuse. In this connection, it should be pointed out that an occasional patient may be encountered with a segmental occlusive process

be peeled away from its mural attachment to this proximal segment of aorta (Fig. 1-22b). After it has been assured that all the thrombus has been removed, an occluding clamp is applied to the freed aortic stump below the renal arteries, and the clamp above is removed, permitting resumption of blood flow to the kidneys.

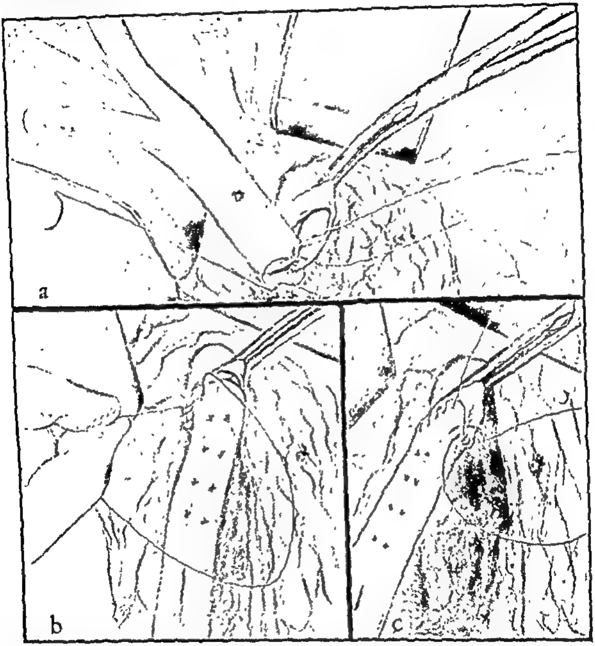

Fig 1-24. (Continued from Fig 1-22) Steps showing anastomosis of aortic homograft a, two sutures of 0000 arterial silk are anchored posteriorly. b, one of these sutures is brought forward for one-half the circumference on the right side. c, the other suture is brought forward in a similar manner on the left side The two sutures are then tied to each other to complete the anastomosis.

The distal aortic segment is next freed from its posterior attachments, with the lumbar arteries being clamped, divided, and ligated as they are exposed. After this segment, along with the bifurcation, has been completely freed, the common iliac arteries are divided, preferably above their bifurcation. The occlusive process in this region usually results more from plaque

If the occlusive process extends above the inferior mesenteric artery, which is often the case, this vessel is divided between ligatures near its origin (Fig. 1-20c). By careful sharp and blunt dissection, the aorta is freed from its surrounding structures from well below the bifurcation to the level of the left renal vein above. Varying degrees of periaortic fibrosis are usually encountered in the region of the bifurcation, producing intimate adherence to the vena cava and underlying left iliac vein. Care should be exercised in dissection in this region to avoid injury to these thin-walled structures. Following mobilization of the aorta below the origin of the renal arteries and the iliac arteries distal to the bifurcation, these vessels are encircled with umbilical tape (Fig. 1-21).

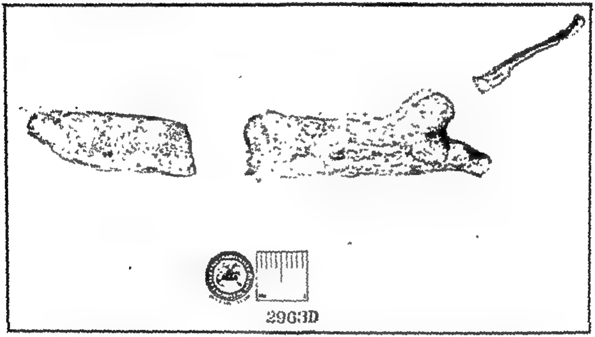

Fig 1-23 Photograph of specimen removed at operation from patient whose aortogram is shown in Figure 1-19 The center segment represents the occluded portion of the aorta and bifurcation, that to the left is the organized thrombus removed from the proximal stump of the aorta, and that to the right is the occlusive process stripped out of the distal end of the left iliac artery

Once the aorta and bifurcation are freed and exposed to this extent, examination by observation and palpation should provide information regarding the extent of the occlusive process and the degenerative mural changes. In most instances, the most extensive degenerative changes will be found about the bifurcation, and the aorta will show a progressively more normal appearance upward near the origin of the renal arteries Even in this upper region, however, the lumen may be partially or completely occluded by organized thrombus, the proximal end of which in some instances projects above the renal arteries, being attached to the anterior or posterior wall of the aorta, leaving a channel on each side for blood flow into the renal arteries. Under these circumstances, the aorta should be mobilized sufficiently above the renal arteries to permit temporary application of an occluding clamp at this level. The aorta may then be transected well below the renal arteries and, preferably, in the region where it is completely occluded by the thrombus (Fig. 1-22a). The partially organized thrombus can then

Restoration of continuity is now accomplished by use of an aortic bifurcation homograft, the anastomoses being performed essentially as described in the case of aneurysms (Figs. 1-21 to 26). Before the anastomosis is accomplished, it is desirable to trim the edges of the proximal aortic stump, as well as those of the iliac vessels below, in order to obtain vascular walls as good as possible for anastomosis to the graft.

Fig. 1-26. (Continued from Fig. 1-25) After completing the proximal aortic and the right iliac anastomoses, an occluding clamp is applied to the left iliac segment of the graft and the remaining clamps removed to permit blood flow through the graft during performance of the other iliac anastomosis

Following completion of the anastomosis of the graft and restoration of blood flow through it, bilateral lumbar sympathectomy may be performed (Fig. 1-27). This procedure is always done in cases in which there is associated occlusive disease involving the vessels below the popliteal artery. Under these circumstances it is considered particularly important to provide,

formation and proliferative intimal changes than from thrombus and it usually extends down to the bifurcation of the common iliac arteries, but in some instances further distally. It is essential to remove this intraluminal occlusive process and obtain good retrograde flow of blood before the vessel is anastomosed to the graft. This can usually be accomplished with relative facility by placing traction upon the firm intraluminal occlusive process

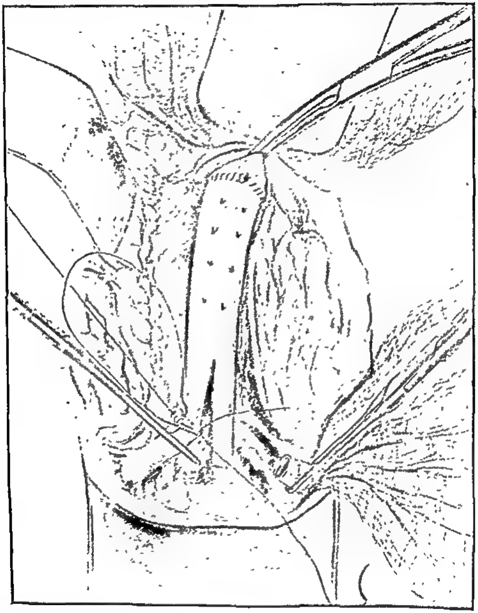

Fig. 1-25. (Continued from Fig 1-24) After completing the aortic anastomosis above, one of the iliac anastomoses is performed using 00000 arterial silk.

and peeling back the loosely attached wall by eversion. If the occlusive process extends beyond the bifurcation of the iliac arteries, its removal may be facilitated by use of a wire loop stripper similar in design to a Mayo vein stripper (Fig. 1-22c)(8). The specimen that is removed under these circumstances has the appearance of a virtual cast of the vessels (Fig. 1-23). It may be desirable in such cases to expose the femoral arteries by separate incisions just below the inguinal ligament to assure their patency.

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through release of constrictor tonus, the maximal degree of vasodilatation in the peripheral vascular bed. Approximation of the edges of the overlying posterior peritoneal layer and wound closure complete the operative procedure.

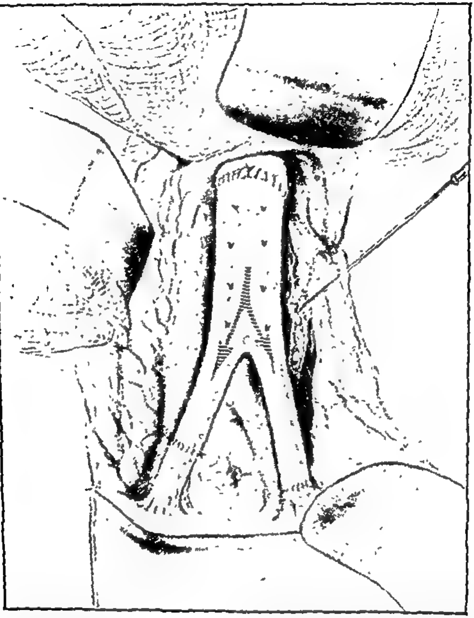

Fig 1-27 (Continued from Fig 1-26) The anastomosis of the graft has been completed permitting restoration of normal blood flow through it. The left lumbar sympathetic chain is being exposed with traction placed on it by a hook to facilitate its extirpation. The chain on both sides is removed from L_2 to L_4 inclusive.

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The single exception to this practice is the presence of acute phlebitis in varicosities in which high saphenous ligation should be done.

Appropriate treatment is further based upon proper evaluation of the individual case, with particular assessment of such factors as patency of the deep veins, adequacy of the arterial circulation, and competency of the valves in the superficial and communicating veins. Of the various special diagnostic tests devised for this purpose, the Brodie-Trendelenburg test (12, 107), Perthes' test(96), and the comparative tourniquet test of Mahorner and Ochsner(67, 90) are most widely used. Probably the most important consideration here is the determination of the patency of the deep venous system.

TREATMENT

As has already been stated, the two principal methods of active treatment are A, injection of the vein with sclerosing solution; and B, ligation with or without extirpation. As a rule, injection treatment is combined with ligation, for when it is used alone it has been found to be followed by a high incidence of recurrence. It may, however, be employed without ligation for relatively small localized varicosities, particularly in the calf, and in the absence of incompetent valves in the saphenous above or in the communicating veins. It may also be justified as palliative therapy in cases in which operative treatment is contraindicated or, preferably, is delayed.

A. **Injection Treatment.** The following equipment is necessary for injection: 1, several syringes (2 ml. and 5 ml. sizes, preferably with finger and thumb rings and Luer-Lok arrangement); 2, needles (22 to 26 inch gauge); 3, sterile sponges and small felt squares; and 4, compression bandages. A number of sclerosing agents have been advocated, but on the basis of the extensive investigation of Ochsner and his co-workers(89, 91) the most efficacious are, in the order given: sodium morrhuate (5 per cent); sodium gynocardate (5 per cent); and quinine urethane. More recently monoethanolamine oleate (monolate)(39, 76), synasol(16), and sodium tetradecyl sulfate (sotradecol)(100) have been recommended as being as efficacious as sodium morrhuate, but without the disadvantage of producing allergic manifestations that occasionally follow the latter agent.

It should be realized, however, that untoward reactions may follow any form of injection therapy. They vary from local inflammatory process or minor allergic manifestations to severe anaphylaxis or fatal embolism(4, 33, 40, 97, 102, 109, 116). Some reactions are due to imperfections in technic and in postinjection management and others to sensitivity of the patient to the agent employed. Their occurrence is relatively rare and with proper precautions the injection method may be used with reasonable safety (72, 74, 80).

Some variations exist in the proper procedure for injections, but adherence to the following principles seems desirable: 1, isolation of the particular segment of the vein to be injected; 2, assurance that the needle is in the lumen of the vein; 3, removal of as much blood as possible from the affected segment of vein before injection; and 4, maintenance of compression of the segment of vein following the injection.

With the patient in a sitting position and the leg hanging down or rest-

V. VARICOSE VEINS AND VENOUS THROMBOSIS

Michael E. DeBakey

VARICOSE VEINS

The surgical management of varicose veins has as its objective the correction or the elimination of the disturbance in the venous circulation which is a consequence of the varicose state. This disturbance, which occurs principally in the superficial veins of the lower extremity and their tributaries, consists essentially in a slowing down of the return flow of blood from the involved area. It is due primarily to two factors, the dilatation of the veins and the incompetency of their valves. When the individual is in the upright position, these factors contribute to, rather than counteract, the effect of gravity which mitigates against the return flow of blood. The normal return blood flow is further affected by the intermittent, excessive back pressure upon the column of blood in the superficial varicosed veins which is produced by coughing or straining and which is normally counteracted by competent valves. Accordingly, there is a slowing down or even a reversal of the circulation and a tendency toward pooling in the varicosed system of veins, with consequent stasis and congestion, which over a long period of time produces undesirable local metabolic disturbances (1, 10, 13, 27, 32, 43, 70, 73, 101).

Obviously reestablishment of original normal function of the involved veins is not possible; rational therapy is therefore directed rather toward the correction or elimination of the disturbance in the venous circulation of the varicose veins. This can be done by obliteration or extirpation of the involved veins, and for this purpose various methods have been devised, ranging from conservative measures to radical surgical procedures. These various methods of treatment, as well as the shifting viewpoints toward their application which have taken place during the past quarter of a century or more, have been adequately reviewed by Ochsner and Mahorner(92) in their comprehensive monograph on varicose veins.

Aside from purely conservative measures, the two basic methods generally employed today, either alone or in combination, are A, obliteration by the injection of a sclerosing solution, and B, ligation of the varicose vein combined with varying degrees of resection. At the present time there is a general tendency toward extension of the surgical method Conservative therapy, consisting essentially in compression by an elastic support, is indicated in those patients in whom active therapy should not be employed, such as persons of advanced age and those with debilitating diseases or with severe arterial disease of the extremity. It is probably better to use conservative therapy, or rather to delay active treatment, in pregnancy until after the puerperium, although under some circumstances particularly in severe symptomatic varicosities surgical treatment may be indicated(98). Active therapy is also better postponed in the presence of cellulitis or other inflammatory states in the involved part until the condition has subsided.

This maneuver confines the sclerosing agent to the desired area and provides for its more intimate contact with the endothelial surface. Following the injection, the needle is allowed to remain in situ for about a minute before it is withdrawn, after which gentle pressure with a felt or gauze pad is applied over the injected segment (Fig. 1-28c). Finally, a compression bandage is applied over the leg and is maintained for a period of four to six weeks (Fig. 1-28d). It is desirable to inject only one vein at the first sitting, in order to determine the individual's reaction to the agent employed. Thereafter, depending upon the character and extent of the reaction, several injections may be made at one sitting, the distance between each injection varying from 2 to 4 cm. It is also desirable to begin the injections at the lowermost area and work upward with successive injections at intervals of three to five days. Depending upon the size of the affected segment of vein, from 0.5 to 2 ml. of sodium morrhuate solution is used at each site, but the total amount used should not exceed 5 to 10 ml.

B. Operative Treatment. 1. High Ligation and Stripping of the Internal and External Saphenous Veins. This is the most effective surgical approach to the treatment of varicose veins of the lower extremities. The procedure of high ligation of the saphenous vein and all of its tributaries at the fossa ovalis is now fairly well standardized and is generally recognized as an extremely important measure in the management of varicose veins. (92, 105, 111). This should be followed by stripping of the long saphenous vein from the groin to the ankle, of the short saphenous vein from the popliteal space to the lower calf, and of any other significant accessory veins of either system. This procedure is the most effective one for completely removing the offending incompetent veins. In addition, by this procedure the communicating veins are disrupted, thus obviating the necessity for individual isolation and ligation of these segments. Unless there are specific contraindications to operation, this procedure should be employed in all cases with involvement of the internal or long saphenous vein. Retrograde injection of a sclerosing solution into the distal segment of the saphenous vein following ligation at the fossa ovalis has been largely abandoned because of the complications resulting from injection of the sclerosing agent, and because of the lack of effectiveness of this procedure. Other procedures, such as high saphenous ligation and stripping of the saphenous vein in the thigh or ligation at multiple points, have also proved less effective than the combination of high ligation and stripping.

The stripping procedure was originally advocated shortly after the turn of the century by Keller(54), Mayo(71), and Babcock(5), but was largely abandoned because of its high morbidity. Its recent revival(28, 31, 42, 44, 49, 50, 65, 103, 108) is based upon the conviction that it provides greater assurance against recurrence by elimination of the varicosities and that morbidity may be kept reasonably low by supplementing the procedure with elastic compression bandages and early activity to combat thrombosis and embolism Various instruments have been devised for this purpose consisting mostly of modifications of the extraluminal Mayo type stripper or the intraluminal Keller or Babcock type stripper.(37, 55, 63, 78, 114, 117). The latter type with a flexible shaft is generally considered preferable.

The operation should be performed in the hospital because the proce-

ing on a stool, the engorged segment of vein to be injected is readily identified and may be isolated between the thumb and index finger of the left hand (Fig. 1-28a). With the distended segment of vein still between the thumb and index finger, the extremity is brought to a horizontal position on the table and the needle attached to the syringe containing the sclerosing

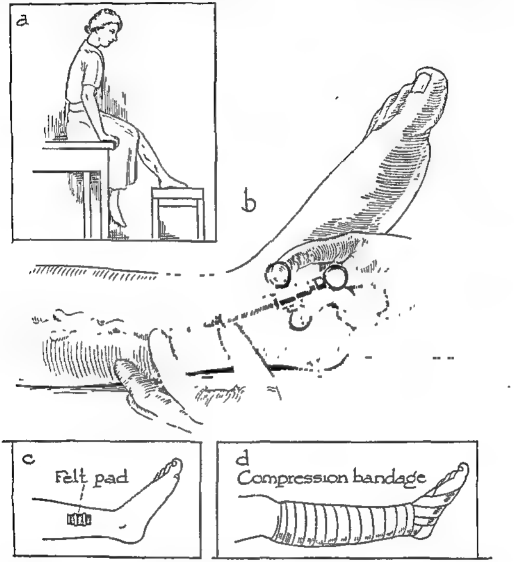

Fig. 1-28 Technic of injection therapy in varicose veins a, with the patient in the sitting position and the leg hanging down or resting on a stool, the engorged segment of vein to be injected [illegible] readily identified and isolated between the thumb and index finger of the left hand. b, with the fingers maintained in this manner the extremity [illegible] brought to a horizontal position *on the table and the needle attached to the syringe containing the sclerosing solution* is introduced into the lumen of the vein The left thumb and index finger are then temporarily removed to allow the segment of vein to [illegible]
and the sclerosing agent is injected into [illegible]
gentle pressure with [illegible] small felt or g[illegible]
d, a compression bandage is applied over the leg

solution is introduced into the lumen of the vein (Fig. 1-28b). After it has been ascertained, by aspiration of a small amount of blood, that the needle is in the lumen, the left thumb and index finger are temporarily removed, to allow the segment of vein to be emptied of blood. Digital pressure is then reapplied and the sclerosing agent is injected into the isolated segment.

encroach upon the lumen of the femoral vein. A transfixation tie is applied just distal to this ligature. Considerable variations in the vascular patterns of the saphenous vein and its tributaries in the thigh have been observed (17, 93, 103), but the significant fact surgically is that all the tributaries near its terminal end enter the main vein within a distance of 2 to 3.5 cm. from the saphenofemoral junction(17). The resection (Fig. 1-29d), therefore, of a segment of the saphenous vein for a distance of about 4 or 5 cm. from its termination in the femoral provides both a reliable means of interrupting all the tributaries and better assurance against subsequent reestablishment of vascular connections with resultant recurrence of varicosities.

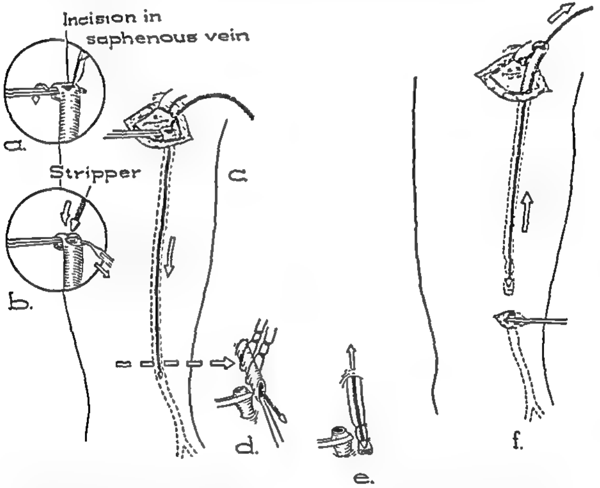

Fig. 1-30 Technic of stripping saphenous vein in the thigh Following high ligation of saphenous vein as described in Figure 1-29, the distal end of the saphenous vein held by the hemostat is incised to open the lumen, into which is threaded the stripper as shown in b and c. The stripper is introduced as far as it will go, in some instances through the entire length of the saphenous vein to the ankle. In other instances, however, the stripper cannot be introduced through the entire length of the vein and under these circumstances additional incisions may be made at the points where the stripper is lodged, as shown in d and e The vein is then exposed at this point by a small transverse incision and after the vein is divided, the proximal end is secured over the stripper head with two ligatures. f, upward traction upon the stripper permits removal of the vein.

Attention is then directed to the distal end of the saphenous vein. Holding the vein with a hemostat, the operator makes a transverse incision into the lumen, after which an intraluminal stripper is introduced into the vein (Fig. 1-30). In many instances, particularly if the vein is not tortuous, the stripper can be passed downward to the ankle, where the saphenous

dure requires a spinal or general anesthetic and because the patient should be under close observation for 24 to 48 hours following the operation. The patient is placed in a Trendelenburg position in order to empty the superficial venous system and thus minimize blood loss during the procedure. A longitudinal or slightly oblique (descending medialward) skin incision is preferable, beginning at the level of the inguinal ligament about 2 to 2.5 cm. medial to the femoral pulsation and extending downward for a distance

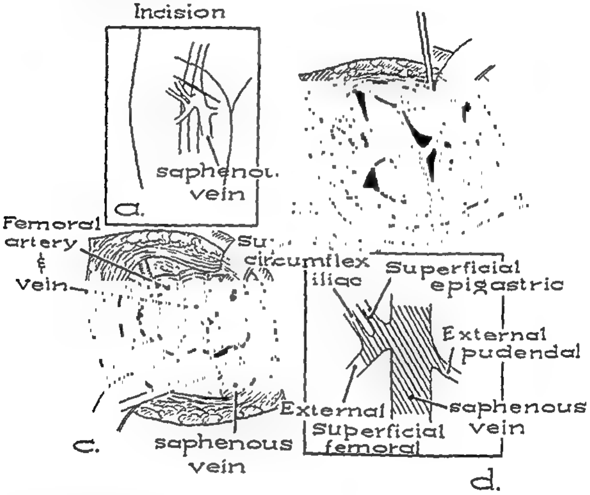

Fig 1-29 Technic of high ligation of saphenous vein and its tributaries. a, oblique incision is made parallel with and just below the inguinal ligament. b, the incision is carried down through the deeper layers of
with the femoral vein to a
its tributaries c, the saphen
which the stripper is inserte
saphenous vein, represented
assurance of interrupting all tributaries of the saphenous vein

of about 10 cm. (Fig 1-29a). The saphenous vein is then exposed as it lies in the deeper layers of the superficial fascia and is freed of its surrounding tissues from the saphenofemoral junction to a point 3 to 5 cm. distally (Fig. 1-29b). This distance is usually sufficient to expose all the tributaries(17). Dissection may be facilitated by working proximally toward the saphenofemoral junction. All the tributaries of the saphenous are identified and individually divided between ligatures (Fig. 1-29c). The saphenous vein is then ligated as closely as possible to the femoral, care being taken not to

encroach upon the lumen of the femoral vein. A transfixation tie is applied just distal to this ligature. Considerable variations in the vascular patterns of the saphenous vein and its tributaries in the thigh have been observed (17, 93, 103), but the significant fact surgically is that all the tributaries near its terminal end enter the main vein within a distance of 2 to 3.5 cm. from the saphenofemoral junction(17). The resection (Fig. 1-29d), therefore, of a segment of the saphenous vein for a distance of about 4 or 5 cm. from its termination in the femoral provides both a reliable means of interrupting all the tributaries and better assurance against subsequent reestablishment of vascular connections with resultant recurrence of varicosities.

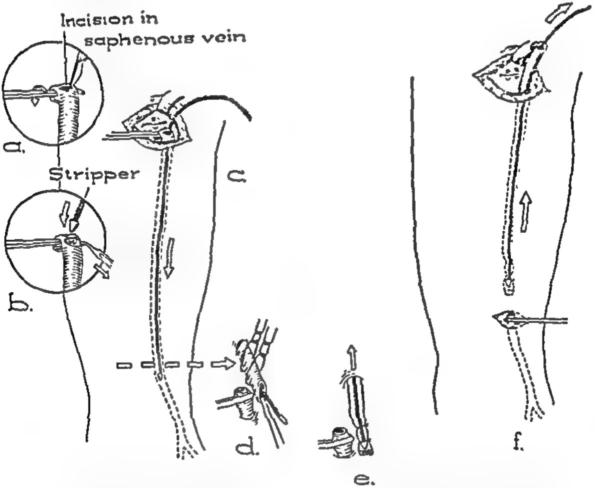

Fig 1-30. Technic of stripping saphenous vein in the thigh. Following high ligation of saphenous vein as described in Figure 1-29, the distal end of the saphenous vein held by the hemostat is incised to open the lumen, into which is threaded the stripper as shown in b and c. The stripper is introduced as far as it will go, in some instances through the entire length of the saphenous vein to the ankle In other instances, however, the stripper cannot be introduced through the entire length of the vein and under these circumstances additional incisions may be made at the points where the stripper is lodged, as shown in d and e. The vein is then exposed at this point by a small transverse incision and after the vein is divided, the proximal end is secured over the stripper head with two ligatures. f, upward traction upon the stripper permits removal of the vein

Attention is then directed to the distal end of the saphenous vein. Holding the vein with a hemostat, the operator makes a transverse incision into the lumen, after which an intraluminal stripper is introduced into the vein (Fig. 1-30). In many instances, particularly if the vein is not tortuous, the stripper can be passed downward to the ankle, where the saphenous

vein lies anterior to the medial malleolus. Here it may be exposed through a transverse incision and the stripper delivered into the wound. The proper size of stripping head is threaded onto the upper end of the cable and the veins are secured below the stripping head with two ligatures (Fig. 1-30d, e). If, for any reason, difficulty is encountered in introducing the stripper from above downward, the long saphenous vein can be readily located at the ankle and the cable threaded up through the saphenous vein and brought out through the incision at the groin. Occasionally, the stripper [illegible] introduced throughout the entire [illegible] [illegible] the long saphenous vein, the s[illegible] drawn through the subcutaneous tissue from above downward, thus removing the long saphenous vein (Fig. 1-30f). In stripping the vein, it should not be inverted but rather should be pulled out in front of the stripping head. In some inst[illegible] drawing the stripper through th[illegible], necessitating a separate inci[illegible] tributary producing the obstruction to the stripper. In pulling the vein stripper through the subcutaneous tissues large tributaries may be avulsed, but with the patient in the Trendelenburg position and the veins relatively empty of blood, significant bleeding does not occur. After the vein has been stripped, compression over the site from which the vein has been removed will be sufficient to produce hemostasis. When large, tortuous tributary veins are present, it may be necessary to strip them individually through separate incisions. When the long saphenous vein and its tributaries have been removed, the incisions are closed and the patient is placed in the prone position for removal of the short saphenous vein. A transverse incision is made just below the popliteal fold and carried through popliteal fascia between the two heads of the gastrocnemius muscle. Here *the short saphenous vein is located as it enters the popliteal vein and is* ligated and divided. The stripper is then introduced and passed downward to a point slightly above and behind the lateral malleolus where another small incision is made and the stripper is removed. The appropriate stripping head is threaded onto the cable above and the vein secured to the stripper with two ligatures and the short saphenous vein is removed by avulsion. The wounds are closed with interrupted sutures, and small gauze dressings are applied. Elastic compression bandages are then applied from the base of the toes to the groin. In the region of the knee the bandage is applied in the form of a figure of eight in order to prevent slipping about the joint.

In some instances it will be necessary to remove segments of veins which have been previously involved in a thrombophlebitic process. These veins are recanalized but are incompetent and must be removed. Because of the thrombosis, it is impossible to pass an intraluminal stripper through the vein, and under these circumstances an extraluminal stripper of the Mayo type should be employed. After ligation of the long saphenous vein at the fossa ovalis or of tributaries to be stripped separately, the distal segment of vein is threaded through the eye of the stripper and the tributaries are evulsed and the vein removed.

The patient is encouraged to walk and to be ambulatory after any of the

operations described above, although as already emphasized it is desirable for him to remain in the hospital for the first 24 hour period. Early ambulation is considered a desirable and effective measure against the development of propagating thrombi.

2. SUBFASCIAL LIGATION OF COMMUNICATING VEINS. In a small proportion of cases (about 2 per cent) with incompetent communicating veins of the legs(80), still *more extensive procedures* than those described will be required to secure a satisfactory result. Such cases are characterized by longstanding varicosities which have resisted ordinary measures and which are *commonly associated with ulceration.* More often than not there is a history of antecedent thrombophlebitis. Under these circumstances it may be found desirable to perform a complete dissection and ligation of the communicating veins of the legs as advocated by Linton(61, 62), though in view of the extensive nature of this procedure considerable care and judgment should *be exercised in the selection of patients for its application.* On the basis of Linton's anatomic studies, these communicating veins may be classified into three groups: medial, lateral, and anterior. The medial group is by far the most commonly involved (80 to 90 per cent) and the anterior group the least (5 per cent). *In cases of ulceration, the location of the ulcer* generally corresponds with the *group of veins involved.*

It is well, in applying this particular method of treatment, to follow the steps outlined by Linton and Keeley(61). It is necessary first to obtain healing of the ulceration which is usually present. In simple cases this may be achieved by conservative management, with elevation of the extremity and application of warm compresses of saline solution. In others, after the large ulcerated surface has been properly cleaned by similar measures, it may be more practicable to cover the granulating area with skin grafts. *The second step* consists of *high ligation* and resection of the long saphenous and its tributaries in the fossa ovalis, as already described. This procedure may be combined with low ligation or with retrograde injection, depending upon the indications previously described. The third step consists of a period of *observation lasting six* weeks or more during which the patient is ambulatory and wears *an elastic* supporting bandage. By the end of this period the condition of the skin of the lower leg should be in sufficiently good conditioning to permit the operative procedure of ligation of the communicating veins, which is the next *(fourth) step.*

The *operation is performed* under general anesthesia or spinal analgesia. The position of the patient, as well as the site of the incision, depends upon the group of veins involved (Fig. 1-31). For the medial group, which is most commonly involved, a longitudinal incision is made on the medial aspect of the leg, extending downward from just behind and below the medial edge of the tibia to just behind the internal malleolus. The incision is carried down through the deep fascia to expose the underlying muscles and the flaps are mobilized on each side for several centimeters in order to obtain proper exposure (Fig. 1-31).

All the communicating veins encountered between these structures are ligated and divided. The most enlarged and most numerous veins are usually found beneath, and in the immediate region of the old ulcer. The wound is closed in layers with interrupted sutures. Immobilization of the leg during

the first 10 days postoperatively is advised to aid healing and is best obtained by a posterior plaster splint. At the end of this period, graduated activity is begun with vascular exercises such as the Buerger type. An elastic bandage applied from the toes to the knee should be worn by the patient for several months or even longer.

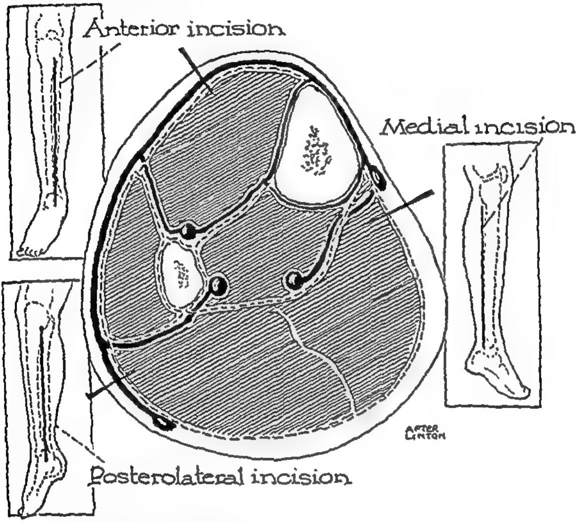

Fig 1-31. Diagrammatic drawing of cross section of leg, illustrating approaches suggested by Linton for ligation of incompetent communicating veins in leg One of three approaches may be used, depending upon the group of veins involved. The medial incision is used for exposure and ligation of the communicating branches extending from the posterior tibial as well as the medial branches from the anterior tibial, the anterior incision is used for exposure and ligation of the central and lateral divisions of the communicating veins of the anterior tibial veins, and the posterolateral incision is used for exposure and ligation of the communicating branches from the peroneal vein

A much less extensive procedure, but one which will often give satisfactory results, as emphasized by Ochsner(80), may also be used in some of these cases in which feeder or incompetent communicating veins exist immediately beneath and around the ulcer bed. It consists essentially in exposing the bed through an elliptical incision, with mobilization of the flaps and resection of the superficial veins, and ligating the feeder or communicating veins. In other cases the old ulcer area with underlying indurated fibrotic tissue and surrounding pigmented skin is completely excised and is covered by a skin graft.

3. **Lumbar Sympathectomy.** In addition to the indicated methods of treatment described, lumbar sympathectomy may occasionally be used in certain types of varicose veins and especially in those associated with chronic postphlebitic syndrome(2, 30, 48, 57-60, 87, 101) In our experience it has proved particularly valuable in bettering results of these modes of treatment. It should usually be done as a preliminary procedure to the more extensive operations on the leg. It is particularly useful in cases with excessive sweating in which chronic fungus infection is difficult to control or in cases associated with cyanosis, induration, and much discomfort and pain. Most of these cases are of the postphlebitic type. It has been demonstrated clinically and experimentally (22, 82-84) that there is a strong factor of vasospasm in the acute form of thrombophlebitis and that interruption of these vasoconstrictor impulses has a desirable effect. There is reason to believe that in the chronic form of the disease some element of vasospasm persists, and on this basis blocking of the sympathetic pathways would produce beneficial effects.

Sympathectomy provides a warm dry skin, permitting effective control of the fungus infection, and, as a consequence of permanent vasodilatation, improves the circulation. It thus encourages healing, helps to relieve discomfort and edema, and in general improves the local condition for subsequent surgical intervention if this becomes necessary. The procedure recommended for lumbar sympathectomy, which has been described elsewhere (89), is removal of the lumbar ganglia and chain through an anterolateral extraperitoneal approach under spinal analgesia.

VENOUS THROMBOSIS

Venous thrombosis may arise under a variety of circumstances in any individual, at any time, and in any part of the venous system. It may develop spontaneously in an otherwise apparently perfectly normal active person, but more frequently it develops as a complication of certain conditions and states, such as trauma, operation, parturition, and other serious bed-confining circumstances. Although it may develop in any part of the venous system, it most commonly occurs in the veins of the lower extremities. There is, however, a special and rather uncommon form of the disease in the upper extremities known as axillary thrombosis or effort thrombosis(25, 69, 110). Clinically there are also variations in both the manifestations and the course of thrombosis Depending upon the particular form it assumes, the process may 1, heal completely without any residual; 2, leave the patient with permanent and often crippling disability, or 3, terminate fatally as a result of massive or repeated pulmonary embolization.

Venous thrombosis thus appears to be a disease of protean nature, although to a great extent this impression may be a reflection of incomplete understanding of its etiology and pathogenesis. This same fact also probably accounts for much of the diversity of opinion concerning therapy. A more detailed consideration of these phases of the subject may be found in previous publications(21, 82-84, 86-88) and the chief emphasis here will be placed upon those pertaining to its surgical management. For the same rea-

son, this discussion will be concerned primarily with thrombosis involving the veins of the lower extremities and pelvis.

Although, as has been indicated above, venous thrombosis may assume a variety [illegible] prognostic and therapeutic purposes, [illegible] two main types of the disease, [illegible] phlebitis(21, 82-84, 86-88). It is believed that in the former the clotting process is due primarily to venous stasis and to alterations in the cellular and fluid constituents of blood which increase the clotting tendency, whereas in the latter it is due to injury to the vascular endothelium from mechanical trauma, chemical injury, or bacterial invasion. Because of the associated inflammatory reaction in thrombophlebitis the clot tends to be firmly adherent to the vein wall and to obstruct its lumen completely. Fragmentation or detachment of the clot, with the consequent occurrence of pulmonary embolism, is therefore less likely to take place, unless suppuration, which is very unusual, intervenes.

On the other hand, in phlebothrombosis, which Homans(46-48) has termed bland or deep quiet venous thrombosis, because of the minimal inflammatory reaction, the clot tends to be lightly adherent to the vein wall and much of its proximal portion forms a loosely floating and incompletely obstructive propagating thrombus. The likelihood of fragmentation or detachment of the thrombus, with consequent pulmonary embolism, is obviously much greater in this form of the disease.

As might be expected, the clinical picture differs considerably in the two forms, there being outspoken manifestations of an inflammatory process in thrombophlebitis and minimal local and systemic reactions in phlebothrombosis. Thus, in thrombophlebitis, the local manifestations of pain, tenderness, and swelling, and the systemic reactions of fever, leukocytosis, and increased pulse rate are quite prominent and the diagnosis, as a result, is relatively simple. Thrombophlebitis is typified by the nonseptic postpartal femoroiliac thrombophlebitis or the classic form of phlegmasia alba dolens. In phlebothrombosis, on the other hand, symptoms and signs are either very mild or are entirely absent, which accounts for Homans'(46-48) application to it of the term deep quiet venous thrombosis. In fact, it may be stated that in general the fixation of the clot is directly proportional to the severity of the clinical manifestation. The more prominent and severe are the manifestations, the more adherent and secure is the clot; the quieter and milder is the process, the less secure is the clot and the greater is the danger of its detachment with resultant pulmonary embolism.

Between these two clinically characteristic forms of the disease there are, as would be expected, intermediate types. It has been clearly demonstrated (7, 8, 38, 51, 52) that in phlebothrombosis the clotting process begins in the deep veins of the foot and leg. Once the process has begun, it may pursue several courses, depending upon a number of factors, many as yet undetermined, influencing the clotting mechanism. It may remain confined to a relatively small area and heal completely without producing any manifestations of its presence. Conceivably, this occurs quite frequently. It may continue to progress upward into the deep venous radicals of the thigh and the femoroiliac vessels, exciting an inflammatory reaction along its attachment to

the vein, fully obstructing these large channels, and resulting in the development of a full fledged thrombophlebitis. In its progression upward along these deep venous channels, the propagating thrombus may grow as a soft fragile mass lightly adherent at some points but to a great extent floating freely, without causing much obstruction. This type is, of course, the most dangerous, for it constantly threatens to produce pulmonary infarction or embolism. Once the process has begun, it may pursue variable courses, and there is no way at present of determining beforehand either the direction or the extent of its course. This, of course, adds greatly to the difficulty of clarifying the problem and standardizing therapy.

Another and perhaps the most striking clinical form of venous thrombosis involving the lower extremities is that termed "phlegmasia cerulea dolens," "blue phlebitis," or "pseudo-embolic phlebitis"(11, 16, 24, 41, 56, 66). It is characterized by a striking, often violent onset with severe pain, edema, cyanotic discoloration of the extremity, and evidence of arterial insufficiency, all of which develop suddenly and may progress so rapidly that the patient goes into shock within a matter of hours or peripheral gangrene develops in the extremity within a matter of days. Fortunately, this form of the disease occurs relatively infrequently, as it is associated with a grave prognosis.

Venous thrombosis may involve the superficial as well as the deep veins of the extremities, whether they are varicosed or not. In them it usually assumes an inflammatory form, with the clot firmly adherent and completely obstructive, though occasionally it may become suppurative.

In addition to these forms of venous thrombosis, which involve the veins of the lower extremities, there is still another important category, in which the veins of the pelvis are primarily involved. This type of thrombophlebitis, which is usually associated with suppuration or with serious infection of the pelvic viscera, is well exemplified by septic postabortal or puerperal thrombophlebitis. This is a particularly serious form because liquefaction of the clot by the infection is likely to occur, and separation of infected emboli produces repeated pulmonary infarction, pneumonitis, and sepsis. The diagnosis is readily apparent, for clinically the manifestations of sepsis are evident; the patient appears acutely ill, with chills, high fever, and a spiking temperature curve.

TREATMENT

Treatment may be divided into 1, prophylactic therapy; and 2, active therapy.

1. *Prophylactic therapy* consists essentially in the correction or avoidance of those factors which are considered to predispose or favor the development of the thrombotic process, including, particularly, circulatory retardation or venous stasis, cardiovascular disorders, dehydration, physical and chemical disturbances in the blood, trauma, and infection. These factors and their control, which should be self-evident, are considered in detail in previous publications(23, 82-84, 86-88). The factor of local circulatory retardation or venous stasis, however, deserves further consideration because of its special importance. The institution of measures directed toward its correction or prevention is particularly important in those conditions or

under those circumstances in which venous thrombosis of the lower extremities seems to occur with relatively greater frequency. Such measures include chiefly restoration of normal cardiovascular function, avoidance of increased abdominal tension, avoidance of postures that favor venous stasis in the lower extremities, the use of deep breathing exercises and leg exercises, early activity and ambulation, and the application of elastic compression bandages to the extremities.

Still another prophylactic measure that may be instituted under certain conditions is the administration of anticoagulants such as heparin and dicumarol. They would seem to be particularly useful in patients with an antecedent or familial history of thrombosis or with other indications of a thrombotic tendency. The use of anticoagulants is not, however, without danger, and close observation of the patient, with repeated laboratory checks, is required when they are employed. For these details of their use, as well as other considerations of their indications, limitations, and contraindications, the reader should consult other publications(6, 9, 19, 29, 36, 53, 68).

2. *Active Therapy.* At present, considerable diversity of opinion exists concerning the most satisfactory treatment of venous thrombosis and several schools of thought on the subject have developed. These range from the most conservative to the most radical, with some advocating, to the exclusion of all other specific measures, the use of anticoagulants, such as heparin or dicumarol, or the use of proximal vein ligation, and others preferring to utilize these as well as other specific measures, such as sympathetic block to produce vasodilatation, depending upon certain conditions and indications in the individual case. Though the advocates of these different methods have marshalled much evidence to support their opinions, the conclusive demonstration of the superiority of any of these particular forms of therapy must await further evaluation. Moreover, it would serve no useful purpose to present here a discussion of the pros and cons of these various modes of treatment. The reader interested in this phase of the subject should consult other publications(3, 6, 9, 19, 21, 46-48, 53, 68, 84, 86-88). Emphasis here will be placed on the method of treatment which, according to our experience, has provided the most satisfactory results.

Uncomplicated Thrombophlebitis. As has been indicated, it is important to distinguish between thrombophlebitis and phlebothrombosis because the therapeutic approach to each condition is different. In thrombophlebitis, with certain exceptions to be indicated, conservative measures combined with induction of vasodilatation in the involved extremity are considered satisfactory. In phlebothrombosis, on the other hand, because of the constant threat of detachment of the clot with consequent pulmonary embolism, it is preferable to employ more radical measures, chiefly the surgical interruption of the vein above the site of involvement(45).

Conservative measures in thrombophlebitis consist essentially in elevation of the involved extremity and the use of an elastic compression bandage, combined with procaine hydrochloride block of the regional sympathetic ganglia. Elevation of the extremity, by the use of pillows or an inclined plane or, preferably, by elevation of the foot of the bed, and the use of a

compression bandage aid the return flow of venous blood and provide for drainage of excess tissue fluid. In addition to these measures, and perhaps the most effective therapeutic procedure in thrombophlebitis, is the production of vasodilatation by means of procaine hydrochloride block of the regional sympathetic ganglia, as originally suggested by Leriche. The rationale of this procedure lies in the clinical and experimental demonstration of the presence of vasospasm resulting from impulses originating in the involved venous segment, probably set up by the inflammatory reaction, and transmitted over the sympathetic pathway(22, 23, 81-84, 86-88). Such vasospastic influences, which probably affect both arterial and venous systems, may be so marked that the condition appears to be arterial embolism and in occasional instances actual gangrene has occurred(16, 24, 56, 66). The mechanism by which it is believed vasospasm contributes to the untoward manifestations has been considered in previous publications(22, 23, 81-84, 86-88). It suffices to say here that these manifestations can be greatly ameliorated by interrupting the vasoconstrictor impulses with procaine hydrochloride infiltration of the regional sympathetic ganglia. Following this form of therapy there occur dramatic relief of pain, rapid subsidence of fever, and early disappearance of edema, and the patients are usually out of bed in five to six days or less. The blocks are performed daily for several days or until the fever subsides. The technic of sympathetic block (Fig. 1-32) is relatively simple(20, 23, 81, 83, 88).

Septic Thrombophlebitis. In thrombophlebitis associated with sepsis or with localized infection or suppuration, more radical therapy is indicated. Occasionally, too, radical therapy is indicated in thrombophlebitis in which there is an acute and rapid progression of the infection proximally along the vein wall, probably through the perivenous lymphatics, with rapid propagation of the clot. In such cases ligation and division of the main venous channel above the involved segments should be done, to prevent extension of the process and the possible occurrence of septic emboli due to liquefaction and fragmentation of the infected clot. The classic and perhaps the most frequent example of this type of thrombophlebitis is the variety commonly observed as a postabortal complication or observed in the puerperium. Despite the effectiveness of chemotherapy, and the even greater effectiveness of penicillin in the management of puerperal sepsis, septic thrombophlebitis still remains the leading cause of death in postabortal and postpartal sepsis (14, 15).

Whereas the measures described should be employed in every case, in many cases venous ligation is additionally necessary for the effective control of the condition. The value of this procedure, as well as the optimum time and the technical methods of its application, are matters that have received much consideration in the older literature(18, 86). The recent revival of interest in it is probably based to a great extent on the unsatisfactory results obtained by the more conservative forms of management and stems particularly from the work of Collins and his associates(14, 15). Their observations, which have been amply confirmed by others(75, 95), demonstrate the value of venous ligation in septic or suppurative pelvic thrombophlebitis.

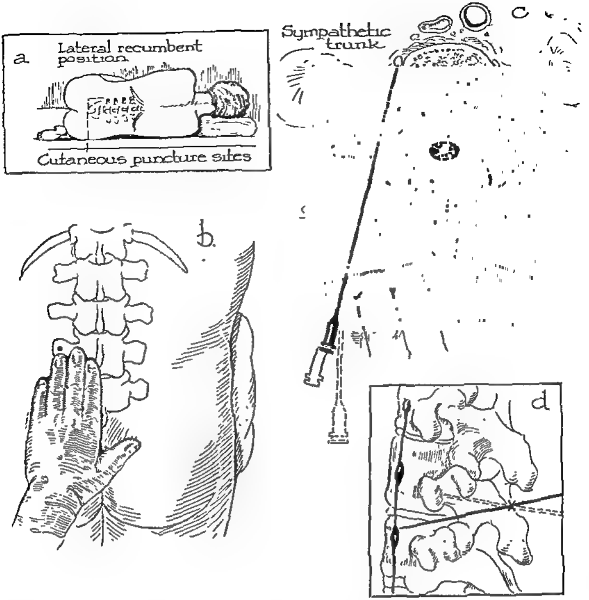

Fig 1-32. Technic of lumbar sympathetic block. The patient may be placed in the prone position with a pillow under the lower abdomen or, preferably, in the lateral recumbent position, as shown in a The cutaneous sites of puncture lie on a horizontal level with, and two and one-half to three fingerbreadths lateral to, the upper part of the spinous processes of the first four lumbar vertebrae This places the cutaneous puncture sites directly over the transverse processes of the respective vertebrae. c, the needle is inserted vertically until the transverse process is reached (dotted needle). A point on the needle and one-half to three fingerbreadths above the skin surface is taken and represents the distance the needle will be introduced further The needle is then directed anteromedially and introduced above or below the transverse process (as shown in d) so that its point impinges against the lateral surface of the body of the vertebra (white needle) *The needle is then withdrawn slightly to slip* away from the body of the vertebra and inserted until the point on the needle previously made has been reached (black needle) Thus, the distance the needle is finally inserted beyond the transverse process is two and one-half to three fingerbreadths and represents the approximate distances between the transverse process and the site of the sympathetic chain Because the sympathetic chain lies snugly against the anterolateral surface of the body of the vertebra, *it is desirable to keep the point of the needle during insertion close to the lateral* aspect of the body of the vertebra until the needle has been introduced the required distance

Since there is generally an extensive involvement of the pelvic venous system, including particularly the uterine, hypogastric, common iliac, and ovarian veins, successful management depends upon complete interruption of the venous return from this area. Accordingly, it is necessary in the majority of cases to ligate the ovarian veins as well as the vena cava. This can best be accomplished by a transabdominal approach, which provides ready access to the pelvis, permitting exploration and simultaneous ligation of the vena cava and both ovarian veins above the thrombotic process (Fig. 1-33).

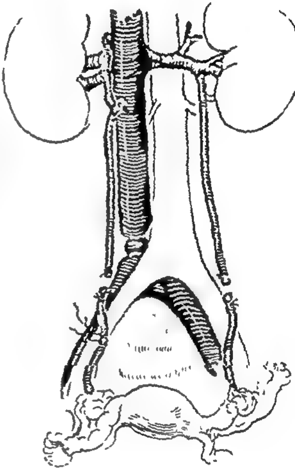

Fig. 1-33 Diagrammatic drawing showing site of ligation of vena cava and ovarian veins in septic pelvic thrombophlebitis. A transperitoneal approach through a low paramedian incision is used. The right ovarian vein and vena cava are exposed retroperitoneally by mobilizing the cecum and ascending colon medially after incising the peritoneal reflection in the paracolic groove. The right ovarian vessels are ligated and divided just above the pelvic brim, or above the clot if they are found thrombosed, care being taken to avoid injury to the ureter, which is usually nearby. Two heavy ligatures about 1.5 to 2 cm apart are placed around the vena cava just above its formation by the junction of the iliac veins. The left ovarian vein is exposed by mobilizing medially the sigmoid and descending colon after incising their peritoneal reflection laterally. The left ovarian vessels are ligated and divided, and reperitonealization is accomplished on both sides. The abdominal wound is then closed in layers.

Section of the lumbar sympathetic chains is advised by Collins, or, if this is considered unwise at the time of operation, daily bilateral lumbar sympathetic blocks with procaine hydrochloride solution should be carried out postoperatively for several days, to counteract the vasospasm which sometimes follows ligation of the vena cava. Other postoperative measures include elevation of the foot of the bed, application of an elastic compression bandage, and early ambulation. Elastic compression bandages, applied from the toes to the groin, should be worn after the patient becomes ambulatory until they are no longer needed to counteract dependent edema. This period varies from several weeks to several months.

Phlebothrombosis. The diagnosis of phlebothrombosis in association with signs of pulmonary infarction is an immediate indication for radical therapy, i.e., proximal venous ligation, because, as previously emphasized, in this form of venous thrombosis there is a constant threat of detachment of the clot and of consequent fatal pulmonary infarction or embolism.

Although this form of therapy is effective in controlling extension of the disease and preventing pulmonary embolism, there may be some difficulty in its practical application in a particular case. This is due primarily to the frequent absence of precise criteria in determining the presence of the disease or in predicting the possible occurrence of embolism. The clinical manifestations of phlebothrombosis are often so mild as to pass unnoticed, and not infrequently the first manifestation of its presence is the sudden occurrence of pulmonary infarction. Because of its insidious development and treacherous nature, the diagnosis, if it is to be made early when therapy is most effective, often must be assumed on the basis of rather minimal findings. These may consist of minor discomfort or slight pain in the foot or calf on movement or palpation, mild swelling in the ankle region, slight dilatation of the superficial veins of the foot, a faint tinge of cyanosis of the toes or nail bed, especially on dependency, and slight elevation of the temperature and especially the pulse. The presence of pain or tenderness in the calf and popliteal area on palpation or on forced dorsiflexion (Homans) is a particularly important sign. Phlebography is a useful diagnostic procedure and when properly performed provides fairly reliable information on the presence or absence of venous thrombosis(7, 8, 26, 34, 35). Unfortunately, it is a procedure that requires considerable experience and skill in both its performance and interpretation and for this reason has not been widely adopted. Furthermore, as clinical experience with the problem of venous thrombosis increases its practical diagnostic value diminishes.

Treatment consists in surgical exploration and division of the main venous channel above the clot. In the majority of instances, the operative site is just below the level of the junction of the superficial femoral vein and the profunda. In other cases, however, the process may have extended to such a level that ligation of the inferior vena cava becomes necessary. It is probably wiser in most cases, and especially in elderly patients, to perform the operation on both sides, since bilateral involvement is not uncommon and since experience has shown that pulmonary infarction or embolism not infrequently arises from the opposite, apparently normal side.

Although the surgical procedure of exposure of the femoral vein and its tributaries in the upper part of the thigh is not difficult, it requires knowledge of the local anatomy and careful operative technic. The patient lies on the table in the supine position, with the upper part of the body elevated to increase venous pressure and thus discourage infarction (Fig. 1-34a). Local infiltration analgesia (1 per cent procaine hydrochloride solution) is adequate. A longitudinal or slightly oblique incision is made, beginning at the inguinal crease, just medial to the femoral pulsation, and extending downward over the course of the femoral vessels for a distance of to 10 cm. (Fig. 1-34b). After division of the superficial and deep fascia, the femoral vein and its tributaries are exposed by careful dissection. Because the femoral artery lies somewhat lateral to, but more or less over, the femoral vein, it is necessary to free the artery sufficiently to allow its gentle retraction laterally (Fig. 1-34c). After the common femoral (superficial), femoral, deep formal femoral (profunda), and saphenous veins have been identified and freed, coarse ligatures or, preferably, soft rubber tubes are loosely placed around them to provide a ready means of hemostasis later (Fig. 1-34c). The

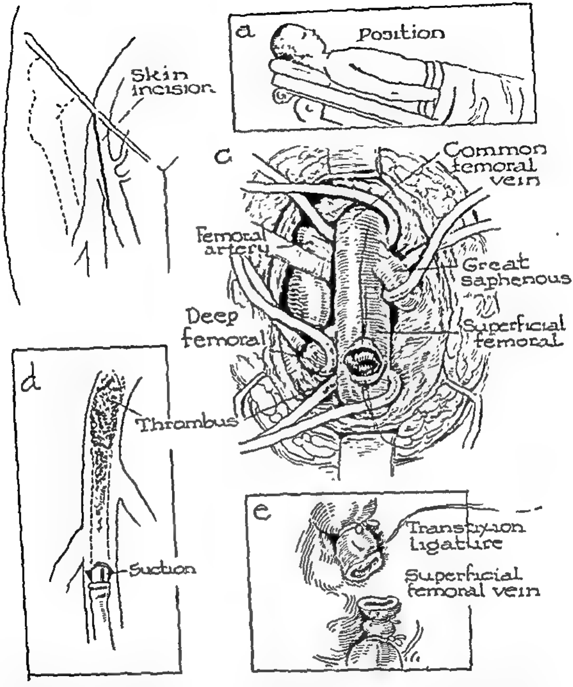

Fig 1-34. Technic of exposure and ligation of femoral vein in phlebothrombosis a, the patient is placed on the table in the supine position, with the upper part of the body elevated to increase venous pressure b, under local analgesia a longitudinal incision is made, beginning at the inguinal crease, just medial to the femoral pulsation, and extending downward over the course of the femoral vessels for a distance of about 8 to 10 cm. c, after division of the superficial and deep fascia, the femoral vein and its tributaries are exposed by careful dissection and coarse ligatures or, preferably, soft rubber tubes are loosely placed around them. The superficial vein is then opened between two stay sutures by a transverse incision in its anterior wall If no thrombus is found and if free bleeding occurs from all of the branches, the vein is divided between double ligatures, those nearest the severed end being transfixion ties. d, if a thrombus, usually in the form of a soft, friable, nonadherent mass, is found, it is removed by gentle aspiration with a glass tube introduced into the upper and then the lower segments, e, following which the two ends of the veins are ligated and divided. If the deep femoral vein is also occluded, it is ligated near its junction with the superficial femoral vein.

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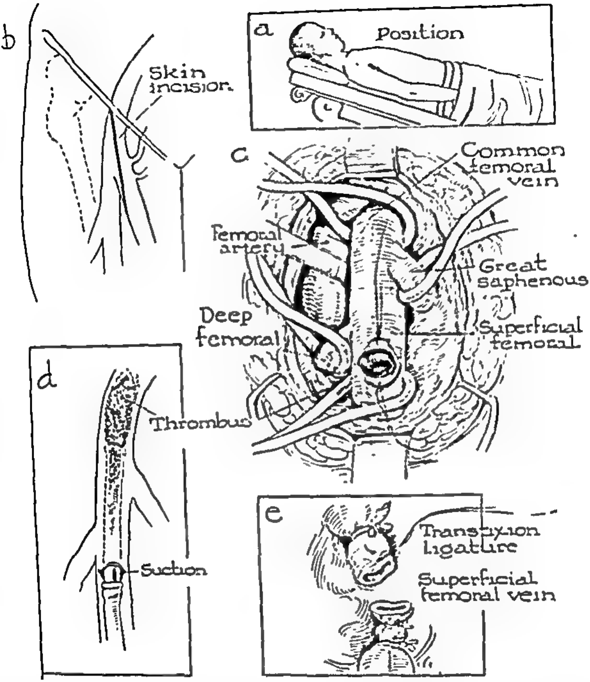

Fig. 1-34 Technic of exposure and ligation of femoral vein in phlebothrombosis. a, the patient is placed on the table in the supine position, with the upper part of the body elevated to increase venous pressure. b, under local analgesia a longitudinal incision is made, beginning at the inguinal crease, just medial to the femoral pulsation, and extending downward over the course of the femoral vessels for a distance of about [illegible] to 10 cm. c, after division of the superficial and deep fascia, the femoral vein and its tributaries are exposed by careful dissection and coarse ligatures or, preferably, soft rubber tubes are loosely placed around them. The superficial vein is then opened between two stay sutures by a transverse incision in its anterior wall. If no thrombus is found and if free bleeding occurs from all of the branches, the vein is divided between double ligatures, those nearest the severed end being transfixion ties. d, if a thrombus, usually in the form of a soft, friable, nonadherent mass, is found, it is removed by gentle aspiration with a glass tube introduced into the upper and then the lower segments, e, following which the two ends of the veins are ligated and divided. If the deep femoral vein is also occluded, it is ligated near its junction with the superficial femoral vein.

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If no thrombosis is found and if free bleeding occurs from all of the branches, which may be readily determined by successively compressing with the encircling ligatures or soft rubber tubes all the branches except the one being tested, the vein is merely divided between double ligatures, those nearest the severed end being transfixion ties (Fig. 1-34c). If a thrombus, usually in the form of a soft, friable, nonadherent mass, is found, it is removed by gentle aspiration with a glass tube introduced into the upper segment (Fig. 1-34d). The lower segment may be treated in a similar manner Complete removal of the clot is evidenced by free bleeding when all the branches are compressed but the one under consideration. If it is determined by this means that the profunda contains no clot, the superficial vein is divided between double ligatures as already described. If the deep femoral vein is also occluded, it is preferable to ligate it in continuity. The wound is closed in layers with interrupted sutures.

The postoperative management of these patients is similar to that already described, particularly as regards elevation of the foot of the bed, the use of elastic compression bandages, and early ambulation.

In the more advanced stages of this form of venous thrombosis, consideration must be given to surgical interruption of the vein at a higher level than that of the superficial femoral vein. Although some have advocated ligation of the common femoral following extraction of the clot above, there are certain disadvantages to interruption at this level. For one thing, it does not provide adequate assurance against recurrence of the process above this point, with subsequent pulmonary infarction. For another, as emphasized by Homans(46), it does not allow an adequate collateral circulation and may therefore be followed by an acute, dangerous venous engorgement of the leg, especially in the presence of fairly extensive thrombosis of the lower venous channels.

For these reasons, and because the method provides a vastly superior collateral circulation, Homans(46) advocated ligation of the common iliac vein in cases of this sort. In a subsequent report(48), however, he seemed to regard ligation of the vena cava as a more logical procedure under these circumstances, since it offers certain advantages over the former procedure, such as alleviation of the need for bilateral operation, and since it is associated with no greater hazard either in its performance or its sequelae than ligation of the common iliac vein. In fact, it may actually be a simpler procedure than iliac ligation, especially on the left side. This opinion has become increasingly widespread among surgeons interested in this problem(77, 79, 94, 95, 106, 112). Accordingly, it is now recommended that in cases in which deep vein interruption is indicated above the level of the superficial femoral vein that ligation of the vena cava be the procedure of choice. The available collateral channels which may function following vena caval ligation have been studied by a number of observers(79, 94, 113, 115), who emphasize their adequacy. It is further evidenced by clinical follow-up observations on these patients, who show remarkably few sequelae. The most extensive clinical and physiologic observations of this kind were made by Ray and Burch(99) who studied 12 patients for periods up to four

and one-half years following vena caval ligation. Their careful observations failed to reveal any detrimental effect from the ligation and showed complete circulatory adjustments.

The approach to the vena cava may be transperitoneal or extraperitoneal. The indications and technic for the former approaches have already been presented. The latter approach, which is preferred for the type of venous thrombosis under discussion here, is quite similar to that used for right

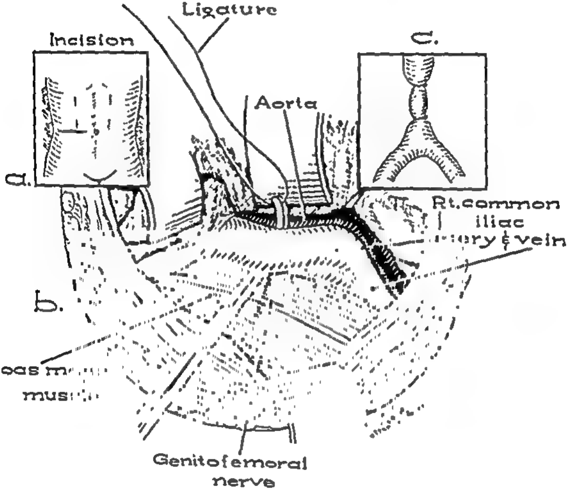

Fig 1-35 Technic of extraperitoneal approach for ligation of vena cava a, under local analgesia an oblique incision is made parallel with and just below the inguinal ligament. b, the fibers of the external oblique, internal oblique, and transversus abdominis are successively separated in the direction in which they run, following which the parietal peritoneum is mobilized medially to expose the iliopsoas muscle and vena cava After the vena cava has been gently freed of its surrounding structures, care being taken not to injure its small lumbar branches, coarse ligatures of silk or cotton are passed around the vessel c, the two ligatures are secured around the vena cava about 1.5 cm. apart with the lower one tied just above the junction of the right and left veins.

lumbar sympathectomy(85). Spinal or general anesthesia may be used, though the former is preferred. The patient lies in the supine position, with the right side slightly elevated by small pillows beneath the hip and shoulder. The incision, which may be of several types, i.e., transverse or oblique, is made in the right anterolateral region of the abdomen (Fig. 1-35a). The fibers of the external oblique muscle and its aponeurosis are separated in the direction in which they run, thus exposing the internal oblique muscle. The fibers of this muscle and of the transversus abdominis,

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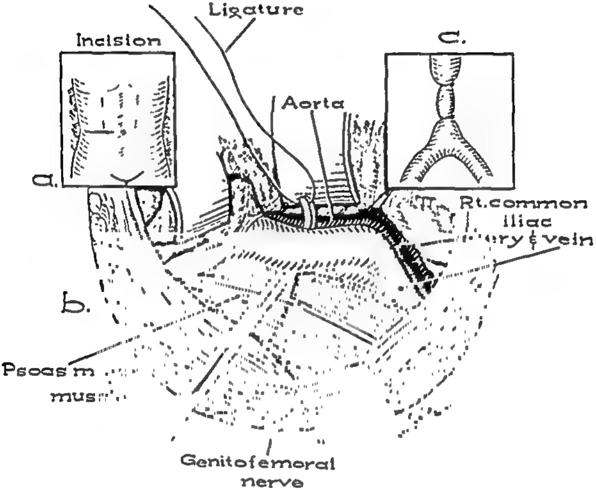

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which lies immediately beneath it, are then split parallel to their course, thus exposing the peritoneum. The posterolateral and posterior parietal peritoneum, with the right ureter, is mobilized medially by blunt dissection to expose the iliopsoas muscle and the vena cava (Fig. 1-35b). Usually the vena cava is fairly mobile and easily compressed. It is gently freed of its surrounding structures at the level of the bifurcation of the aorta, care being taken not to injure its small lumbar branches, which can produce troublesome bleeding. A coarse ligature, such as heavy braided silk or No. 8 cotton, is passed around the vessel by means of a curved ligature carrier and is tied securely (Fig. 1-35b). A second ligature is similarly secured around the vessel about 1.5 cm. higher (Fig. 1-35c). It is preferable not to open and explore the vessel. The wound is then closed in layers with interrupted sutures.

The postoperative care of these patients is much the same as that already described above, particularly as regards elevation of the foot of the bed, the use of elastic compression bandages, and early ambulation.

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2

THE HEART AND PERICARDIUM
EXCLUDING CONGENITAL AND VALVULAR LESIONS

CLAUDE S. BECK

CARDIAC ARREST AND RESUSCITATION (1, 2, 3, 4)

This presentation on resuscitation concerns patients who stop breathing in the operating room. While it may be possible to carry out successful resuscitation of patients who stop breathing elsewhere in the hospital, the major problem concerns the resuscitation of patients who stop breathing in the operating room. The necessary apparatus is available in the operating room. If it is not available, it should be. Methods for successful resuscitation have been in existence for a good many years(5). We surgeons and anesthetists have been slow in applying these methods, but every surgeon who operates should be familiar with them. We owe this to society. Indeed it can be stated that any patient with a good heart and good lungs who stops breathing in the operating room can be resuscitated successfully. It is a tragic loss of life if the surgeon is not prepared to take care of one of these emergencies when the crisis occurs.

The resuscitation procedure should be divided into two parts. Part 1 concerns the restoration of the oxygen system, and part 2 concerns the restoration of the coordinated heart beat. These two parts of the resuscitation procedure should be regarded as separate and independent steps in the procedure.

Part 1. Restoration of the Oxygen System. This is the emergency part of the resuscitation procedure (Fig. 2-1). In order to maintain life, a constant supply of oxygen to the brain is necessary. Brain cells disintegrate in a few minutes with lack of oxygen. Lack of oxygen to the brain is responsible for a good many of the children with cerebral palsy. The child at birth may not be breathing adequately, the airway may be obstructed, and the newborn baby may need mechanical respiration. If proper steps are not taken at the time of birth, the child may become one of this large group of children classified under cerebral palsy. In the operating room, if the patient stops breathing or if the heart stops beating, the brain immediately begins to undergo degenerative changes. If the anoxia continues for five minutes or so, these degenerative changes become irreversible. Usually it is a simple matter to restore the heart beat. If the resuscitation procedure is not carried out properly, the heart beat may be restored to a patient who has entered a vegetative condition. The period of anoxia that can be tolerated by the brain cells without damage is influenced by temperature. The oxygen requirements are greater in high temperatures and reduced by low temperatures. Individuals have been taken out of a cold lake after having been

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submerged for a period of 10 minutes and complete recovery was obtained. For our purpose we can assume that there is a period of three to five minutes which can be taken to restore the oxygen system after it has once broken down.

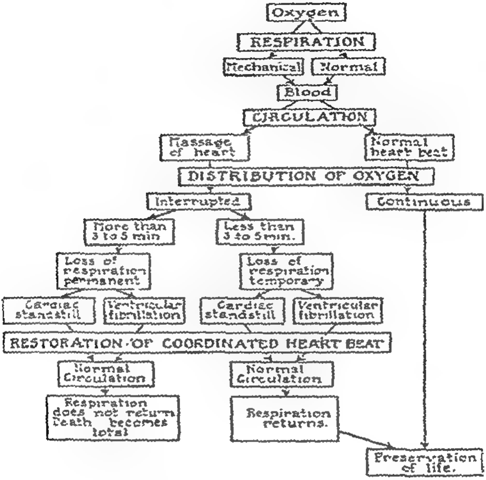


Fig. 2-1. Oxygen and resuscitation. This chart indicates the transfer of oxygen from the outside air to the inside structures of the body. (From Beck, C. S. Am. J. Surg., 54:273, 1941.)

The oxygen system can be restored by doing two things: 1, delivering oxygen into the lungs; and 2, circulating the oxygen by squeezing the heart. In order to do these two things an intratracheal tube is necessary. A laryngoscope is also necessary and someone must be available to introduce the tube into the trachea. If an intratracheal tube cannot be introduced, then tracheotomy should be done. A rubber bag filled with oxygen is also necessary and someone must squeeze the bag to deliver the oxygen into the lungs. In order to do these various simple steps within the time limitation we must be prepared. We are not doing the best for our patient if someone has to get an intratracheal tube and if someone else has to run off for oxygen and a rubber bag. These things should be available at the head end of every patient who has any surgical procedure done on him whether it be done under general anesthesia or local anesthesia. Every hospital should make it a rule that these items are immediately available for every patient.

After the oxygen has been delivered to the lungs, it must be circulated so that the brain can pick it up. This can be done only by squeezing the

heart. In order to do this one must slit open the chest immediately and get the hand on the heart. Time is not taken to count the ribs for the incision, to put on gloves and gown, or to cleanse the skin. One knows approximately where to make the incision. It is made from the sternum out to the left axilla and is carried through the intercostal tissues; the cartilage above and below is cut across with a knife and a retractor is inserted into the wound so that the wrist of the person who is going to squeeze the heart will not become strangulated by the pressure of the ribs on the wrist. Someone can pull the ribs apart while a self-retaining retractor is obtained. The heart is then grasped by the hand and it is emptied of blood. The rate of squeezing the heart is limited by the rapidity of the filling of the heart. It does not fill fast enough as a rule to squeeze the heart more than about 60 times per minute.

There are several methods by which the heart can be squeezed. One can put the right hand beneath the heart and squeeze it against the sternum. In children the thumb can be placed over the right ventricle and the fingers over the left ventricle and, in this way, the heart can be emptied satisfactorily. A third method is to use the fingers of the right hand over the left ventricle and two fingers of the left hand over the right ventricle. With experience one can make a blood pressure of 80 mm. of mercury or even higher. However, there are precautions concerning this maneuver. The heart should not be squeezed so hard that the heart muscle is ruptured or bruised. It has happened more than once that a student in our resuscitation course actually stuck his finger into the left ventricle. Another point in the technic is to reduce all pressure on the heart during the phase of filling. The pressure that brings about cardiac filling is very slight and the heart must be free to receive blood Some years ago Mr. James Rand made suction cups which we could apply to the heart. These suction cups were used to pull the heart apart, so to speak, and in this way blood filled the heart more rapidly than was possible without them. With this more rapid filling the heart could be squeezed more times per minute and in this way a larger volume of blood could be moved(6).

It is not always necessary to split open the pericardium from base to apex, and I would not take the time to do this as soon as the chest is opened. I would squeeze the heart immediately and create some circulation and later, if the heart cannot be grasped satisfactorily, the pericardium should be opened and the heart examined. As a rule the pericardium is opened. The lungs should be well inflated and well deflated. The lungs should come up and go down nicely in repeated cycles about 20 times per minute. Lack of proper inflation and deflation of the lungs may be the cause of failure. The surgeon may be so intent on squeezing the heart that he will not notice the movement of the lungs. The lungs should not be distended constantly. They should come up and go down nicely in each cycle. A breathing machine is helpful if the procedure extends over a long period of time. In most instances, however, success is achieved in 10 or 15 minutes and the bag of oxygen can be squeezed satisfactorily by the anesthetist for that period of time. Once the oxygen system is established the crisis is over. The surgeon can then take time to take a few breaths for himself and reduce his own tension. Things are under control after these various steps have

been taken properly. One can take an hour or several hours before the second part of the resuscitation procedure is carried out.

Are these the only effective steps in order to restore the oxygen system? In my opinion these are the most effective steps that can be taken. If the necessary equipment is not available, then the surgeon considers alternative steps, such as trying to inflate the lungs by blowing into the patient's mouth, or by squeezing the chest. Precious time may be taken by injection of adrenalin into the heart through the chest wall. Someone might even try to give an intra-arterial transfusion of blood. Someone else might get an electrocardiogram to see for sure whether the patient is dead. Can the heart be emptied by squeezing it from beneath the diaphragm? The heart has been started by this maneuver and it is probable that touching it or squeezing it started it to beat. My experience is that a satisfactory blood pressure cannot be produced by trying to squeeze it from below the diaphragm. An electric shock to defibrillate the ventricles cannot be applied effectively from below the diaphragm. If the abdomen is open when the heart stops beating, the surgeon can try this manipulation, but I would not waste opportunity if the heart does not start to beat immediately. I would be in favor of opening the chest and working on the heart under direct vision. If a tube cannot be inserted into the trachea, I would be in favor of doing a tracheotomy. We cannot accept failure because of inability to introduce a tube into the trachea.

The position of the patient is flat on the back. The table might be tilted so that the head is on a lower level than the feet by about 6 to 12 inches. This allows blood to drain from the legs and abdomen into the heart, but at the same time the veins in the arms and head do not empty as well as if the patient were horizontal.

Part 2. Restoration of the Heart Beat. When the heart stops beating it shows one of two conditions: either the heart is in ventricular asystole or it is in ventricular fibrillation. It is usually possible to differentiate these two conditions by examination of the heart. When the heart is in standstill, there is no motion of the ventricular musculature. When it is in ventricular fibrillation, one can see fine or coarse contraction waves that pass over the musculature. Sometimes these waves, like ripples on a quiet pond, begin in one small area on the heart and move out from this area to the entire musculature. Sometimes the fibrillation is so fine that an electrocardiogram is necessary for its recognition. In any event an electrocardiogram is valuable as proof that the ventricles are fibrillating. Methods for handling standstill and fibrillation are quite different.

For Cardiac Standstill. Squeezing the ventricles is often sufficient to start a coordinated heart beat. Often the heart will start beating after the ventricles have been squeezed a few times. In these instances restoration of the heart beat is no problem. I had one patient whose heart started beating without opening the pericardium. The individual who is squeezing the heart notes the tone of the ventricles. He knows whether the ventricles are flabby and soft or whether the myocardium is firm. If it is firm, a coordinated beat can be restored quickly. If it is flabby, then the tone of the heart must be improved by the use of adrenalin. A small amount of adrenalin is injected into the cavity of the right ventricle. This adrenalin is moved through the

lungs by squeezing the heart. It comes back to the left ventricle and then small traces of the drug enter the coronary arteries and reach the myocardium. It is possible to feel the tone restored to the heart, and when one feels this he can be assured that the heart is going to start beating. A normal heart wants to beat provided the conditions are proper for it to do so.

FOR VENTRICULAR FIBRILLATION. In the human heart ventricular fibrillation rarely stops spontaneously. As a rule it is necessary to shock the heart out of fibrillation. This is done by using special apparatus which should be available in every operating room. It is dereliction of responsibility for any hospital not to be provided with a defibrillating instrument. This defibrillating device can be made by an electrician, or it can be purchased from the Rand Foundation of Cleveland, which makes them without profit. A current of 110 volts is used. Resistors are placed in the apparatus to reduce the amperage to about 1½ amperes. The amperage can be increased or reduced. The electrodes are large, approximately 6 cm. in diameter. If they are small they may burn the heart. The surgeon must protect himself against the current. The handles of the electrodes are insulated. In our operating rooms these electrodes are kept in a sterile package. The current is turned on for about a second or two. Sufficient time must be given for the current to go through the myocardium. A circuit is made and broken as the current is applied to the heart. The skeletal muscles will contract and a jerk of the patient can be expected. The passage of the current through the myocardium causes all the muscle fibers to contract at one time while the current is applied. Then, when the current is broken, it is to be expected that the muscle fibers will relax uniformly without some of them going back into fibrillation. If the fibrillation ceases with the shock, you then have simplified the problem to that of standstill and the same procedure is carried out as outlined in the discussion under Standstill. Sometimes the heart will go back into fibrillation and, when this occurs, the shock must be reapplied. It may be necessary to use a drug to reduce the irritability of the heart so that it will remain in standstill. We discovered that novocain was effective in reducing the irritability of the heart so that it would remain in standstill after the electrodes were removed.

Drugs and Their Application. In general there are only two drugs necessary for successful resuscitation. These drugs are adrenalin and novocain. We advocate the use of small quantities of these drugs. The drug effect is obtained by way of the capillary circulation rather than by injection into the myocardium. If a drug is injected locally into the myocardium, only a localized effect is obtained. If it is injected into the blood stream so that it reaches the capillary bed, then a generalized effect is obtained. We found that perhaps the most satisfactory way to administer drugs was to inject them into the cavity of the right ventricle. Two 10 ml. syringes should be available and an 18-gauge needle is about the proper size. Adrenalin solution 1:1000 is diluted 10 times with normal saline. Three to 5 ml. of this diluted solution is the usual dose of adrenalin. The needle should be inserted at an acute angle through the myocardium rather than inserted perpendicularly to the surface of the heart. If the puncture wound is at an angle, there is less likelihood of bleeding after the needle is withdrawn. The surgeon should be careful not to stick the needle into a coronary vein

or artery. Novocain is used in either a 1 or 2 per cent solution and the usual dosage is 5 ml.

Another drug that we have found to be of value is digitalis. We made this discovery in our course in resuscitation. Dogs that have been given cedilanid (intravenous digitalis preparation) showed remarkable tendencies toward defibrillation. The hearts that were digitalized could be thrown into and out of fibrillation almost as many times as one desired. If we are having difficulty in restoring the heart beat in the human patient, I suggest that an intravenous digitalis preparation be administered. Other drugs have been advocated for the resuscitation procedure. Calcium gluconate will increase the tone of the heart, but I do not think that it is as effective as adrenalin.

Closure of the Chest. The surgeon should observe the heart beat for a sufficiently long period of time so that he can be reasonably certain the heart is going to keep on beating after he closes the chest. It is unnecessary to suture the pericardium. If the pericardium is not closed, the opening in it should be large enough to prevent herniation. In other words, the pericardium should either be widely open or closed allowing only for drainage of fluid. One should be careful about the internal mammary vessels. These vessels might be cut when the incision is made, but since there is no blood pressure there will be no hemorrhage. On restoration of pressure these vessels might begin to bleed if cut and not ligated. Intercostal vessels should also be clamped and ligated. The incision in the chest is then closed as any thoracotomy is closed. It is advisable to put in a drainage tube and also to introduce antibiotics into the chest cavity and to administer these for several days thereafter. The patient may require oxygen or even mechanical respiration after the heart beat has been restored. In some instances intravenous fluid should be given and, if the heart beat is weak, adrenalin should be added to the intravenous fluid so that a small amount of this drug goes in with the glucose or saline.

Causes of Failure. 1. Too slow to get started. This is one of the most common causes of failure. The anesthetist may not recognize that the heart beat has stopped. The surgeon also may not recognize that death has occurred. One may feel for the pulse or listen for the heart beat for too long a period of time. In some instances time is even taken to get an electrocardiogram during these moments of crisis. In one instance of which I know the surgeon called in the Baltimore Fire Department to bring a pulmotor to the Johns Hopkins Hospital. Some surgeons have exposed an artery and given an intra-arterial transfusion during these first few minutes of crisis. In other instances the surgeon was so confused that he did not know what to do. Every surgeon who operates and every anesthetist who gives anesthetics should know what to do without needing to think about the problem. The steps to be taken should be established by reflex mechanism brought about by training for the emergency. Hospitals should conduct a drill on resuscitation in which a dog's heart is fibrillated and defibrillated; everyone on the staff should be familiar with the procedure. Such an exercise should be done once every year so that surgeons and anesthetists will be constantly prepared: As soon as the heart stops beating there is no alternative to the immediate establishment of the oxygen system.

2. Inadequate oxygenation of the lungs. As already stated, the lungs must come up nicely on inspiration and then go down nicely on expiration. The lungs should not be kept in a state of continued distention. I feel that I cannot overemphasize this point. A properly fitting intratracheal tube with inflatable cuff is essential. If a good fit is not obtained, the lungs cannot be properly inflated.

3. Inadequate circulation. The brain will be damaged if adequate circulation is not maintained. At no time can the oxygen system be stopped for more than a few moments in order to observe the heart or to apply electric shock. At all other times oxygen must be circulated by proper squeezing of the heart. This part of the procedure may have to be maintained for one, two, or three hours. Adequate exposure of the heart is necessary to empty the heart. Both ventricles must be emptied and not just the left.

4. If the procedure is applied for a period of several hours and if a closed gas system is used, it may be necessary to change the soda lime for absorption of carbon dioxide. Failure to absorb carbon dioxide can interfere with the restoration of the heart beat.

5. Intrinsic heart disease. Anatomic conditions may be present in the heart which preclude successful resuscitation. In my experience these conditions have been glycogen storage disease, or von Gierke's disease, coronary artery disease, congenital defects of the heart such as interventricular septal lesions, pulmonic stenosis, and mitral stenosis. In one of my patients who was being operated upon for mitral stenosis, whose heart stopped beating before the valve was opened, the mitral valve was opened in about 10 seconds and a coordinated heart beat was restored in 12 minutes. The oxygen system was maintained during this period so that there was no brain damage. In this instance mitral valvulotomy became a prerequisite to successful resuscitation. One of my patients with severe coronary artery disease was successfully resuscitated, but I have also had a number of patients with severe coronary disease who could not be resuscitated after working on them for several hours.

Discussion. Recently I was called in my own hospital to help resuscitate a child who had an operation on his eye for strabismus. When I arrived in the operating room the lungs were well oxygenated, and the surgeon, who had taken our course, had made an incision over the precordium about 6 cm. in length and had introduced two fingers into the chest to squeeze the heart I was not able to empty the heart through this incision. The incision was enlarged to about 12 cm. in length and two costal cartilages, one above and one below the incision, were cut. After this was done I was able to empty the heart. A self-retaining retractor was an important aid in providing the necessary exposure. After the heart was emptied repeatedly for about three minutes the pericardium was opened. Adrenalin and later cedalanid were given through the right ventricle. The heart was defibrillated. After 90 minutes a coordinated beat was obtained. Respiration returned. The child had slight convulsive movements of the extremities. On one occasion he seemed to recognize his mother. Twelve hours after the chest was closed the child died.

Why did this child have cerebral damage and die? The correct answer

can be given. Even though the lungs were inflated the oxygen system was not restored until I enlarged the incision and emptied the heart. Up to that time the oxygen system was broken down. You cannot empty the heart through a buttonhole incision.

The only way to learn the resuscitation procedure is to practice it on the cadaver and on the dog. It is one of the simplest and at the same time one of the most elusive procedures in surgery. Many surgeons believe they understand resuscitation. Indeed, some have written papers on the subject. Yet, when it comes time for application of the procedure, there is hesitation, confusion, and failure to understand the precise nature of the emergency act. The right thing is not done. In this procedure there can be no trial and error experimentation. It is an obligation to do the right thing at the right time in every one of these crises.

Conclusions. Any patient with normal heart and normal lungs can be resuscitated successfully if the proper steps are taken. Every surgeon and anesthetist should be familiar with the resuscitation procedure. Every hospital administrator should be obligated to provide a defibrillating device for use in the operating room. A practice session should be carried out once a year in every hospital so that the staff will always be alerted to the requirements of the procedure(7, 8).

PRESSURES ON HEART(9)

Abnormal pressure in the pericardial cavity or in the mediastinal space can interrupt the circulation. The auricles and venae cavae are collapsible structures and readily yield to outside pressure. Normally these structures carry blood at a negative pressure, that is, less than the pressure of the atmosphere. The effect of intrapericardial pressure is shown in Figure 2-2. It is readily seen that there is a relationship between pressure in the pericardial cavity and pressure in the veins as they enter the pericardial cavity. Pressure in the pericardial cavity tends to collapse these veins. Pressure on veins produces stasis in the veins and venous pressure rises. Venous pressure must be high enough to force blood into the heart; if blood does not enter the heart then, of course, the circulation stops. The pressure in the vena cava must be higher than the pressure in the pericardial cavity. The height to which the venous pressure can rise determines the height to which intrapericardial or mediastinal pressure can rise before the circulation is stopped

Measurements. Venous pressure is an index of intrapericardial or mediastinal pressure. It is measured directly by introducing a needle into a vein at the elbow and allowing physiologic solution of sodium chloride to run into the vein. The vein at the elbow must be placed at the same horizontal level as that of the right auricle. The patient lies relaxed in recumbent position on his back. The arm is elevated on a pillow so that a vein at the elbow lies at the junction of the anterior and middle third of the anteroposterior diameter of the chest. A needle is introduced into the vein; it is connected to a manometer and the height of the column of fluid is the pressure. Normally the venous pressure measures 3 to 6 cm. Anything below 10 cm. is considered normal.

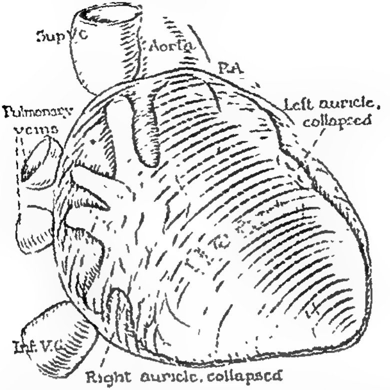


Fig. 2-2. The heart is compressed by fluid in the pericardial cavity The heart is smaller than normal The intrapericardial segments of the venae cavae and the right auricle are compressed. The venous channels outside the pericardium are distended. (From *Textbook of Surgery by American Authors* Edited by Frederick Christopher, 3rd ed Courtesy W B Saunders Co.)

Triad for Acute Compression of Heart(10). Acute pressure in pericardiac cavity produces a clinical picture that can be readily recognized. It consists of 1, a small quiet heart; 2, a falling arterial pressure, and 3, a rising venous pressure. The effect of acute pressure applied to the intrapericardial structures is shown in Figure 2-3.

Acute compression of the heart develops in a variety of conditions It develops in stab wounds of the heart and in other conditions in which blood collects in the pericardial or mediastinal space. Rupture of the base of the aorta produces it as does also hemorrhage from a neoplasm of heart or pericardium. It develops in traumatic cases involving the trachea and producing pressure in the mediastinum. Infection with gas forming bacteria may produce pressure. It is seen also in purulent pericarditis where pus compresses the heart. It also develops in rapidly forming effusions without infection.

Triad for Chronic Compression of Heart(10). Chronic pressure applied to the heart also produces a clinical picture that can be readily recognized. It consists of. 1, a small quiet heart; 2, venous pressure at the elbow higher than 18 to 20 cm. water; and 3, ascites and a large liver. The effect of chronic pressure on the heart is shown in Figure 2-4.

Chronic compression of the heart is seen in a variety of conditions. Any of the acute conditions may become chronic. Effusions may be absorbed and scar tissue may form around the heart. These scars may undergo contracture which in time compress the heart.

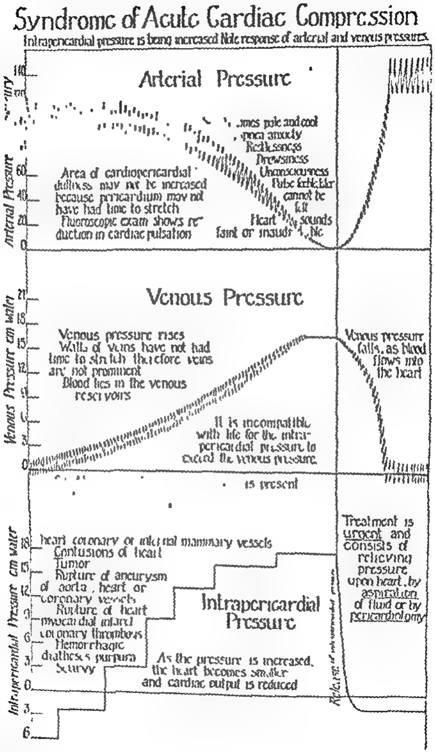


Fig. 2-3. Syndrome of acute cardiac compression Intrapericardial pressure is being increased. Note response of arterial and venous pressures. (From Beck, C. S. Am Heart J., 14.515, 1937.)

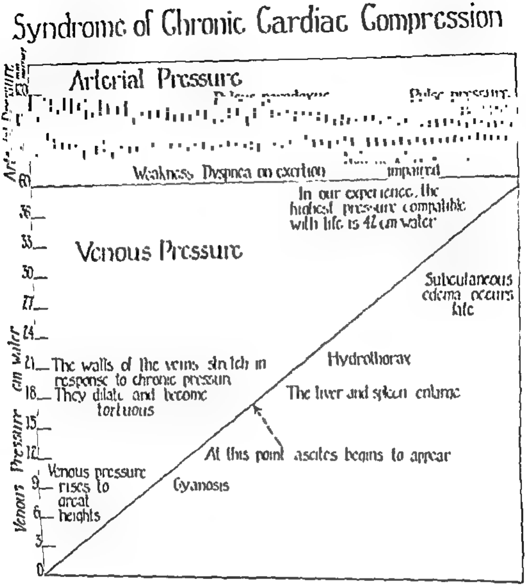
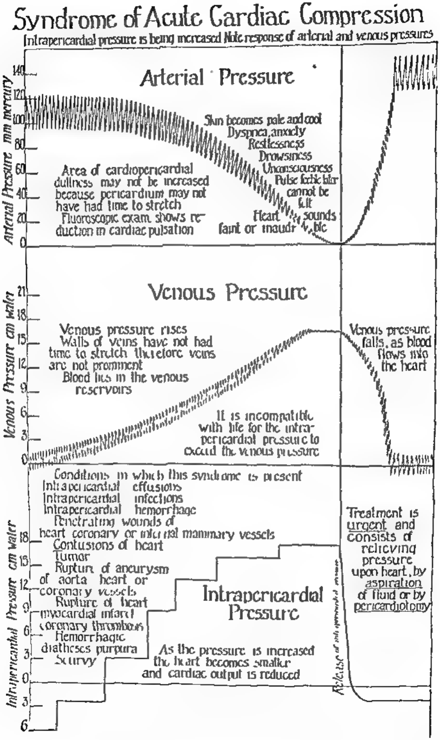


Fig. 2-4. Syndrome of chronic cardiac compression. (From Beck, C. S. Am Heart J, 14 515, 1937)

PENETRATING WOUNDS OF THE HEART

Causes of Death. Extensive wounds of the heart may produce death immediately. The heart can be shot to pieces as occurs in war. In civilian life less severe injury to the heart is inflicted by stabbing with a knife or with an ice pick. The heart may tolerate such injury well. The seriousness of this type of injury is due to complications of the penetration rather than to the intrinsic injury to the heart itself There are four causes of death as follows: 1, intrinsic damage involving the conduction system, a valve or papillary muscle, a major cononary artery or extensive destruction of myocardium, 2, exsanguination which may occur inside the chest or through the wound to the outside, 3, compression of heart by collection of blood under pressure in pericardial sac or in the mediastinal space; and 4, degeneration of brain due to anoxia. Examination of the patient is ried out with these possibilities in mind.



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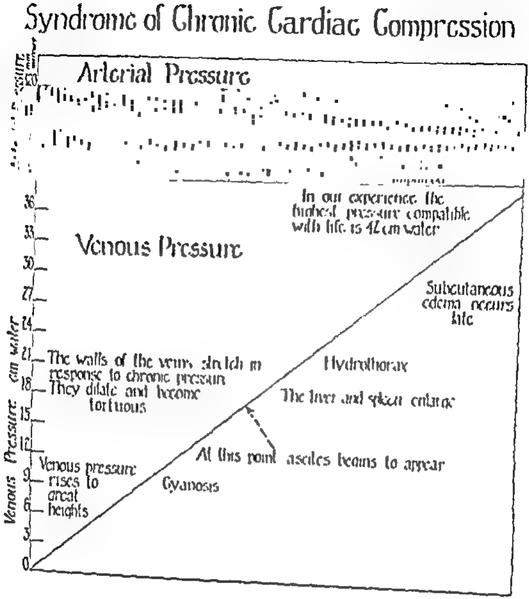

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Indications for Operation. Some patients recover without operation. A small penetration of auricle or ventricle may be tolerated without operation. It should be stated also that a small penetration which could be repaired readily by operation can cause death if operation is not done. Patients may be classified as follows: 1, patients with acute cardiac compression who improve under observation and recover without operation; 2, patients with cardiac compression who become progressively worse and require operation; 3, patients with compression plus internal hemorrhage, and these usually require operation; and 4, patients with severe injury with external hemorrhage in whom operation is urgent. There is some difference of opinion concerning indications for operation and it is difficult to draw the line between the groups. It should be stated that the surgeon should not be too conservative and exploration should be done if *life is threatened.*

Determinations of arterial pressure and venous pressures are helpful in determining whether operation should be done. Venous pressure is an index of compression of the heart. Venous pressure and pressure applied on the heart run parallel. A pressure of approximately 15 cm. water applied to the heart will kill a dog. The average venous pressure in Griswold's cases was 20 cm. Each of these had severe compression. In most of these the arterial pressure could not be obtained or it was down to 40 or 50 mm. mercury. In one patient it was 94 mm. mercury. The lowest venous pressures were 11 and 15 cm. water and the highest were 26 and 28 cm. These determinations agree more closely with experimental values than do the determinations of Elkin who has obtained readings as high as 40 cm. water.

Four out of 28 patients in Elkin's series were not operated upon. Three of these recovered. They were patients in whom the compression or tamponade was not progressive and in whom the venous pressure did not rise. Elkin(11) stated that it is a dangerous procedure to watch a patient who is developing pericardial compression since delay may prove fatal. He believes that fluoroscopic examination should be done at the bedside to avoid moving the patient. He doubts "the efficacy of drainage by aspiration since the pericardium will certainly refill in one or two minutes if bleeding is still active." Elkin cited one patient who died three weeks after he received a suspected wound of the heart. Death was due to rupture of a traumatic aneurysm of a coronary vessel and Elkin was of the opinion that this death might have been prevented had the patient been treated by operation rather than by conservative measures.

According to Bigger(12), it would appear that the indications for operation are determined, first, by the status of the patient at the initial examination and, second, upon the direction of shift of this status in the period immediately thereafter. If the circulation can be made to improve by any nonoperative measures it would appear advisable to proceed upon a nonoperative program. Patients with severe compression are taken to the operating room. While preparation for operation is made the pericardial sac is aspirated one or more times. If the circulation improves, the operation can be delayed. If it does not improve, operation is done without delay.

Griswold(13) believes that if compression is serious [illegible] to require aspiration then operation with suture of the wound [illegible] of the

pericardium into the pleura is the treatment of choice. Free bleeding into the pleural cavity is an indication for immediate operation. If blood is being lost to the outside, into a pleural cavity or into the mediastinum, then these nonoperative measures are of no value and time is not to be wasted on them. It may require nice judgment to know when to go forward with operation without wasting valuable minutes. Some of these patients are in a bad condition. One should not hopefully delay operation in such cases. Griswold states that death may occur in the hospital during the first few minutes that it takes to make the diagnosis and start operation even with the best organization.

Preoperative Measures. The patient is placed in bed on his back. The head is lowered if the patient is in shock. Morphine is given if the patient is restless. If the patient is in severe shock, fluid is given intravenously (saline, glucose, gum acacia, plasma, blood). If the surgeon decides that he should observe the patient before operation this might be done more safely in the operating room while preparation for operation is carried out.

Anesthesia. In most instances general anesthesia is desirable. Nitrous oxide and oxygen together with a little ether is recommended. Deep anesthesia is not necessary nor desirable. If the patient is cooperative, the operation can be done under local anesthesia. Bigger was able to do the operation under local anesthesia in 5 out of his 17 operations. As a rule the patient is not cooperative. Some are intoxicated with alcohol; some are excited by pneumothorax and air hunger. It is advisable that these patients who show excitement be under a general anesthetic because the patient must be quiet for the surgeon to perform the operation. A mechanical respirator is of great help in some of these operations. It gives the surgeon an opportunity to save patients in whom the oxygen system has completely broken down. It is of value also in the less severely injured because the lungs can be properly ventilated by the machine and the pleural cavity can be opened without hesitation. Griswold believes that a minimum of inhalation anesthesia is advisable although oxygen under positive pressure is usually necessary on account of the open pleura. His preference is intercostal novocain block, usually of the third to sixth nerves, supplemented by oxygen and a minimum of nitrous oxide.

Incision. The wound of entrance can be almost anywhere in the body. Usually it is over the precordium to the left or to the right of the sternum. It may be over the abdomen or back. In one instance, a bullet entered the perineum and lodged in the heart and in other instances, sharp bodies like needles penetrated from the esophagus. Most commonly the wound is inflicted by a knife, an ice pick or a pistol. The location of these wounds in Bigger's cases and in Elkin's cases is shown in Figure 2-5.

Different types of approach to the heart have been described. The most simple type is an approach to one side of the sternum Two or three costal cartilages are removed or cut across close to the sternum so that they can be retracted. The fourth and fifth, or the third, fourth and fifth, are the cartilages selected. The incision in the skin is made in a transverse direction at the level of the fourth or fifth ribs; sometimes the wound of entrance in the skin can be included in the incision The margins of the stab wound or the gunshot wound are excised The medial end of the incision

can be curved upward along the sternal margin to the level of the third costal cartilage giving the incision the shape of a hockey stick (Fig. 2-6). Elkin extends the incision across the sternum to get sufficient exposure and Griswold uses a T-shaped incision. The pectoral muscle is cut along the incision in the skin and the costal cartilages are exposed. If the wound of entrance is well over to the right side of the sternum, the incision is placed on the right side. Otherwise, it is made on the left side.

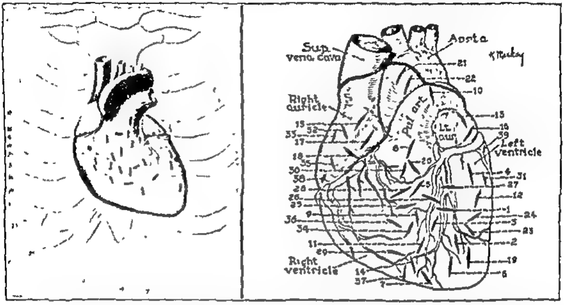


Fig 2-5 Location of wounds Left, cases of Bigger. It would appear that wounds 4, 10, 5 and 18 could be approached better from the right side of the sternum than from the left side (From Bigger, I. A South M. J, 33.6, 1940) Right, cases of Elkin. It would appear that wounds 15, 32, 33, 17, 18, 35 and 38 could be approached better from the right side of the sternum than from the left. (From Elkin, D C Ann. Surg., 114.169, 1941.)

The operator must decide whether he can take the time to remove costal cartilages As a rule they are cut across rather than removed. The soft tissues are cut along the sternum and the mediastinal space is entered, following which the internal mammary artery and vein are ligated. The pleural cavity is widely opened. If the condition of the patient is critical a more rapid exposure of the heart is carried out by making an incision through the chest wall between ribs and costal cartilages. Costal cartilages are cut across at the sternal ends, one or two on each side of the incision, and the parts are retracted.

There may or may not be free bleeding from the wound in the pericardium If the pericardium is distended with blood and if there is little or no free bleeding from the pericardium, the problem is one of compression rather than one of exsanguination. However, the pleural cavity may contain a large quantity of blood and the bleeding from the pericardial wound may have stopped. The blood can be removed by suction and can be given back to the patient. The pericardium is opened and the wound is located. Elkin found it possible to place sutures in the wound before the heart started to beat. The method of handling the wound depends upon several considerations.

Refusion of Blood. It is recommended that the blood from the operative field be collected into a sterile bottle by means of suction. A glass or

metal suction tip may be used. The glass bottle should contain sodium citrate or heparin to prevent clotting. The blood that has been recovered is filtered through several layers of gauze to remove clots. It is placed in a bottle and given into a vein. This may be done during the operation. Additional blood may be given during or after operation.

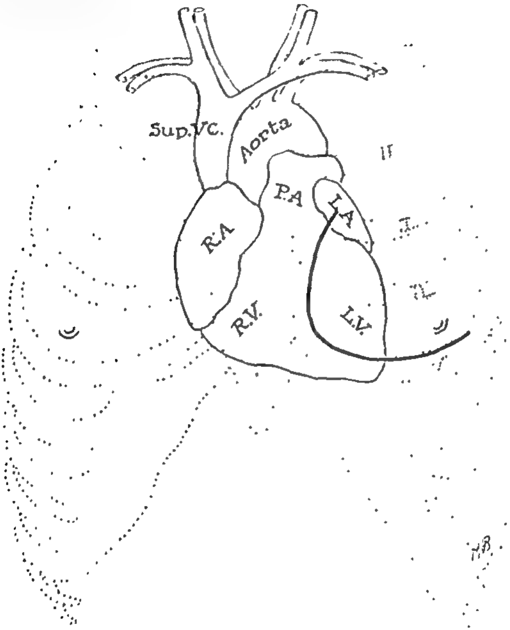
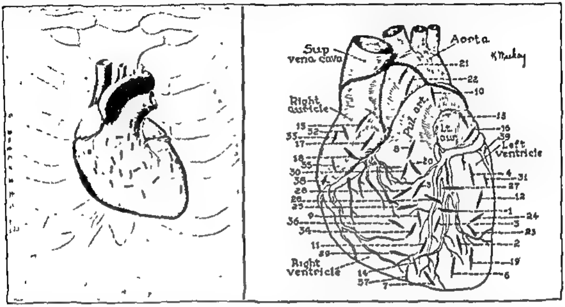


Fig. 2-6. Usual incision for exposure of the heart. It can be made on either side of the sternum

Repair of Ventricular Wounds. The best way to stop bleeding from a ventricle is by placing a finger upon and not in the wound. It is difficult or impossible to keep the finger on the wound because of the movement of the heart. It slides off and there is a squirt of blood. However, it can be kept on the wound fairly well if the heart is steadied by a suture. This can be done by placing a suture in the apex of the heart and holding this suture between thumb and third finger of the left hand while the index finger of that hand is placed upon the wound. In this way the hand moves with the heart and you do not get so many squirts of blood (Fig. 2-7). The

can be curved upward along the sternal margin to the level of the third costal cartilage giving the incision the shape of a hockey stick (Fig. 2-6). Elkin extends the incision across the sternum to get sufficient exposure and Griswold uses a T-shaped incision. The pectoral muscle is cut along the incision in the skin and the costal cartilages are exposed. If the wound of entrance is well over to the right side of the sternum, the incision is placed on the right side. Otherwise, it is made on the left side.



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Refusion of Blood. It is recommended that the blood from the operative field be collected into a sterile bottle by means of suction. A glass or

apex was selected for this suture because this region is farthest from the major coronary arteries and there is least likelihood of inflicting injury to one of these important arteries in this location. Often the surgeon wants to place the suture without delay because of bleeding. To inspect the heart in order to find a place for the suture takes time. The apex is always a favorable place for it. These points originated from experiments upon

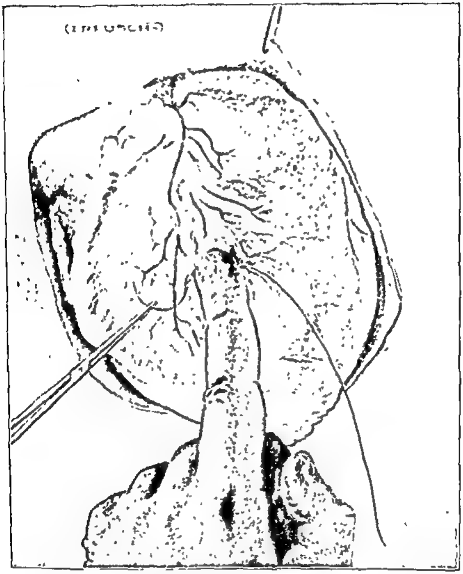


Fig 2-8 Left index finger placed upon wound as in Figure 2-7. Suture then placed across the wound under the finger This suture is used for traction and hemostasis until other sutures are used. (From Elkin, D C. Ann Surg., 95:573, 1932.)

dogs by Beck. Griswold(13) refers to this part of the operation as follows: "There is nothing more disconcerting than to hold in one's hand a writhing, jumping heart and blindly attempt to find a wound deep in a gushing whirlpool of blood. The insertion of a traction suture converts this stage of the operation from the futile blundering into an orderly process. The traction suture steadies the jumping organ so that a finger may be placed over the opening temporarily to staunch the flow."

The next step consists in repair of the wound. According to the original method of Beck, a traction suture was placed at each side of the finger at

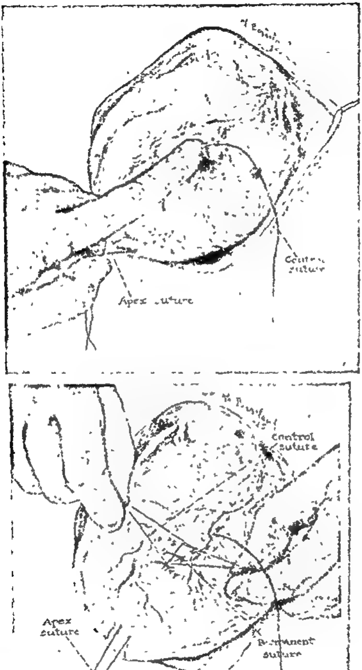
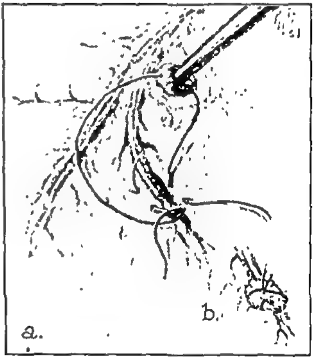


Fig 2-7 Control of hemorrhage from wound preparatory to suture. Traction on apex suture steadies heart so that index finger can be kept on the wound. Top, suture is placed on each side of the finger at the level of the wound Bottom, the control sutures are crossed and held by the assistant The finger is removed and the wound is exposed. The wound can be repaired by permanent sutures Coronary artery should be avoided. (From Beck, C. S. Arch. Surg., 13:205, 1926)

that it would be better to close the operative incision and take the chance of having to reopen it if bleeding and tamponade occurred" (14). The patient recovered without this complication developing.

Repair of Auricular Wounds. The methods for the control and repair of ventricular wounds cannot be applied to the repair of auricular wounds. A finger placed on an auricular wound will not stop the bleeding because the auricle is invaginated by the finger and the flow of blood continues. Another point of difference is in the character of ventricular muscle and auricular muscle. The former is friable and is readily broken so that a hemostat cannot take hold of the muscle. The auricular wall does not break in a clamp. The margins of an auricular wound can be held in an ordinary hemostat. Special hemostats are not necessary for this but light ones are preferable to heavy clamps. The margins of the wound are brought together by the clamps. This stops the bleeding and the wound can be repaired by sutures. These methods are illustrated in Figure 2-11 (15).

Fig 2-10 Method of stopping bleeding from coronary vein. A small muscle graft is applied to the vein in such a way that the artery is not occluded. This suture is not tied too tightly. A mattress suture may be used to hold the muscle graft. (From Beck, C. S. J.A.M.A., 97:824, 1931.)



Drainage of Cardiac Wounds. Blood is removed from the operative field by suction. The pericardium is loosely closed by sutures so that fluid can freely drain into the pleural cavity. A drainage tube is placed in the pleural cavity just above the diaphragm and attached to a water seal in a bottle on the floor. Fluid can be removed from the left chest by aspiration. Air is sucked out of the wound and every precaution is taken to avoid pneumothorax.

Postoperative Considerations. An oxygen tent is a great help to these patients after operation. The chest must be examined frequently, and if air is found in the pleural cavity it should be aspirated. Blood transfusions and morphine are given as indicated. Quinidine is indicated if a coronary artery was injured and if tachycardia is present. If fluid collects in the left

the level of the wound beneath the finger. Coronary arteries were avoided in these sutures. They were crossed over the finger and gentle traction was applied by the assistant as the finger was removed. This exposed the wound and if the sutures were properly placed there was no bleeding from the wound. The wound was then repaired. Elkin modified this method by placing a temporary suture under the finger and across the wound. Traction upon this suture stopped the bleeding (Fig. 2-8).

If the wound lies along a coronary artery, there is a possibility of including the artery in a Lembert repair suture. The method of repair of such a wound is shown in Figure 2-9.

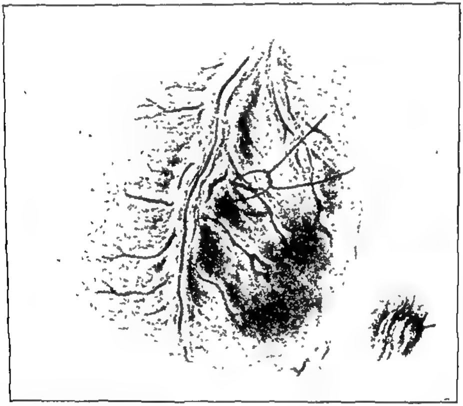


Fig. 2-9 Method for repair of wound situated adjacent to coronary artery. The wound can be closed by one or more mattress sutures without sacrificing the coronary artery. (From Beck, C. S Ann Surg, 115.698, 1942)

Bleeding from a coronary vein can be controlled by placing a small muscle graft upon the vein in such a way that the sutures do not occlude the adjacent artery (Fig 2-10). Slight pressure by the graft controls the venous bleeding without producing arterial occlusion. This method may be useful to control bleeding from the surface of the heart after resection of pericardial scar.

Bigger sutured the pericardium into a wound for closure In his case the muscle was very soft and friable and sutures had a tendency to tear out. Cushing's brain clip is useful to occlude a coronary artery that is severed by a stab wound. Bigger had a case in which "the injury was so close to the main stem of the artery it was felt that if an attempt were made to ligate the injured vessel which had stopped bleeding, it would in all probability be necessary to ligate the main artery. It was decided therefore,

the sternum and the steering wheel. The heart is compressed between sternum and vertebrae. Any severe blow over the precordium may produce contusion of the heart.

Treatment. Most of these patients recover spontaneously and diagnosis is not made. For the severe contusions the treatment is similar to that given to patients with myocardial infarct. An oxygen tent is helpful. Morphine should be used. Quinidine is given if tachycardia is present. The patient is kept quiet to prevent rupture of the heart. This may occur after softening of the contusion takes place. This may blow out and produce death by acute compression.

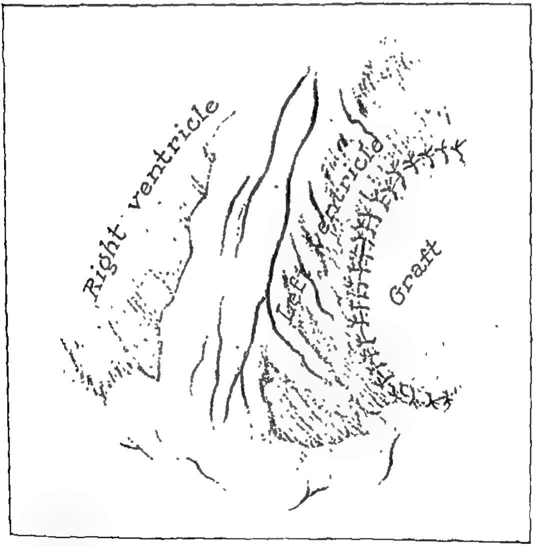


Fig. 2-12 Graft of parietal pericardium or fascia lata placed over area of contusion in left ventricle. (From Beck, C S Ann Surg, 116.161, 1942.)

None of these patients have been operated upon. All those in whom rupture has taken place have died. Death is not always immediate. In some cases opportunity to operate was present. It is possible to place sutures in the area of contusion and it is possible to place a graft of pericardium over this area to reinforce the area to prevent rupture (Fig. 2-12).

pleural cavity after the drainage tube is removed it should be removed by aspiration.

Prognosis. In Bigger's series, 11 out of 17 patients with penetrating wounds of the heart recovered. In Elkin's series 22 out of 38 recovered. In a recent survey Bigger found that 141 patients were operated upon by American surgeons. Of these, 71 patients recovered, a recovery rate of about 50 per cent.

According to this compilation it appears that wounds of the left auricle have a low recovery rate, and also wounds of the left ventricle and pulmonary artery have a low recovery rate. On the basis of other data it appears that the gunshot or bullet wounds are less favorable than stab wounds(15). Wounds made by an ice pick appear to be more amenable to treatment than wounds made by knives and other cutting instruments.

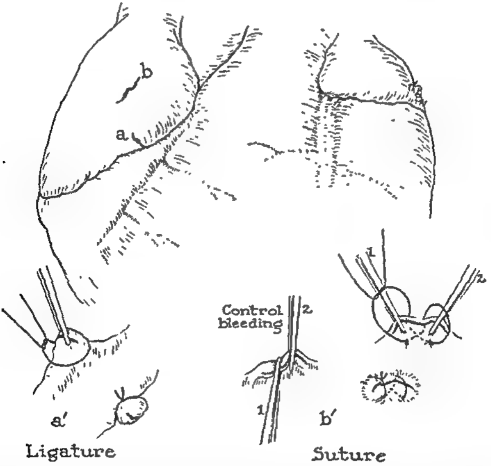


Fig. 2-11 Methods for repair of auricular wounds A marginal wound is grasped in a clamp and a ligature is applied as shown in a. Elsewhere the edges of the auricular wound are grasped in small hemostats, the points of the hemostats brought together and sutures are applied as shown in b (From Beck, C S. Ann Surg, 115 698, 1942.)

CRUSH AND OTHER NONPENETRATING INJURIES OF THE HEART(16, 17)

Incidence. In the writer's opinion this type of cardiac injury is more common than the penetrating injury. The heart tolerates bruising well. The heart can be severely bruised in the steering-wheel type of injury in which the body is hurled forward with the vertebral column approaching

monary artery or if it might fall into the blood stream, then the best judgment is to try to remove it.

Operative Removal. The approach is either to the left or to the right of the sternum depending upon the location of the foreign body. Removal of foreign bodies from the pericardial cavity and from the surface of the heart offers no problems that need discussion.

If the foreign body is embedded in the myocardium, the technic of removal consists of fixing the foreign body with sutures in the wall of the heart. Several such sutures are placed. The myocardium is then incised over the foreign body while traction is placed on the sutures. The foreign body is readily removed in this manner (Fig. 2-13). The sutures prevent the foreign body from falling into the cavity of the heart. They also help to control hemorrhage after the myocardium is cut. Closure of wound is done with silk sutures.

Removal of a needle from the heart may be a difficult problem. The writer removed one by squeezing the heart together parallel to the needle. The needle emerged posteriorly from the heart and it could not be removed posteriorly because there was not sufficient space to extract it. It was then pushed through the heart emerging anteriorly where it was grasped and removed.

It need scarcely be stated that the optimum time to remove the foreign body, as a rule, is immediately after it enters the heart and before adhesions obscure its location.

PURULENT PERICARDITIS(20, 21, 22)

The diagnosis is often missed. The existence of this condition should be considered in any patient with pneumonia or osteomyelitis who has unexplained fever. The common organisms found are pneumococcus, staphylococcus, and streptococcus. Other organisms have been found. The organism may enter by direct extension from lungs, pleura, and mediastinum or it may be brought in by the circulation. The formation of exudate is rapid and although the pericardial structures dilate, pressure is produced on the heart. Usually the compression is the acute form but if the fluid forms slowly the compression may be chronic. The clinical picture of purulent pericarditis is the picture of acute or chronic compression together with that of sepsis. Diagnostic tap should not be delayed. These patients are critically ill.

Treatment. Treatment consists of combating the infection by use of sulfa drugs and penicillin together with the release of the cardiac compression by removal of the pus. The simplest way to remove the pus is by aspiration but usually the pus is thick and cannot be removed satisfactorily by aspiration. In these cases open drainage should be done. If removal by aspiration is feasible, penicillin should be injected directly into the pericardial cavity in doses of 100,000 units. This can be repeated. It is possible that aspiration of pus and the introduction of penicillin into the pericardial cavity will cure these patients so that open drainage may not be necessary. The writer recommends that this treatment be tried before operation is decided upon.

FOREIGN BODIES IN HEART AND PERICARDIUM (18, 19)

These consist of needles, fragments of shell, bullets, point of a knife, piece of wood or stone and fragments of sternum or rib that are driven into the heart. A needle that has been swallowed may enter from the esophagus. Other foreign bodies may enter from the blood stream. Some are swept through the heart.

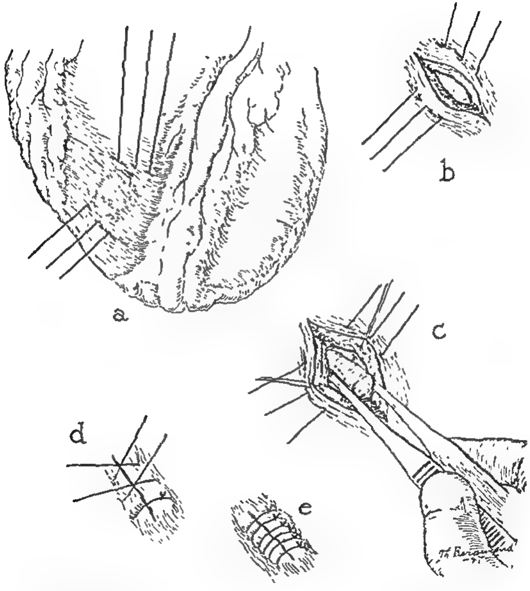


Fig 2-13 Sutures placed in myocardium around foreign body so that the foreign body is not dislodged into the ventricular cavity These sutures also aid in hemostasis.

Treatment. Removal of almost all foreign bodies should be done if removal is feasible. Some foreign bodies are small and when embedded in the myocardium seem to be safe. These need not be removed. Any sizable foreign body like a bullet, or an irregular piece of metal or a needle should be removed, if removal is possible. If the foreign body has been lodged in the heart for a period of months and produces no symptoms it might be good judgment not to try to take it out. If, on the other hand, the foreign body might erode through the heart or through aorta or pul-

2, the scar when first formed did not produce compression and it was only after the scar underwent contracture that compression of the heart was produced; 3, compression of the heart could be general over the entire heart or localized to one part of the heart. It could be right sided primarily or left sided primarily. The right auricle could be compressed and the left ventricle could be free. The aorta, pulmonary arteries or vena cava could be the chief site of compression; 4, muscle fibers of the heart underwent atrophy of disuse after compression and the entire heart became a small shrunken organ; 5, the blood volume increased in the presence of compression to maintain high venous pressure which is compensatory; 6, the threshold for formation of ascites expressed in terms of venous pressure is 18 to 20 cm. of water. Pressures above this level are accompanied by ascites. Pressures below this level are not accompanied by ascites, 7, acute dilatation of the heart can follow the removal of a compression scar; 8, a buffer of fluid might accompany the scar in production of compression. The compression agents in such cases are both fluid and scar; and 9, the compression agent is extrinsic to the heart, i e., outside the heart and it involves the heart only in a secondary way. If the extrinsic lesion can be removed the heart can be restored to a perfectly normal organ(24). The author's series of cases has been reported by Chambliss and his associates. Sixty-one patients were operated upon(25).

Diagnosis. This should not be difficult although there is some confusion in the diagnosis of this condition The diagnosis can be made frequently by inspection alone. A patient with an abdomen distended by fluid, with dilated veins in neck and arms, and with a quiet precordium has compression of the heart. A direct measurement of venous pressure at the elbow is made. In the presence of ascites the venous pressure in the arm is above 18 cm. water. In the preascitic stage the venous pressure may be lower. The quiet heart is checked by fluoroscopic examination and by kymograph x-ray. The compressed heart is always a quiet heart. The compression may be localized and this can be determined by x-ray. The compressed heart is necessarily a small heart. It cannot be large. If the shadow is large then you must suspect fluid as the compression agent rather than scar. Some of the compression scars are 1 cm. thick and a thick scar may increase the apparent size of the atrophic heart.

All other manifestations of compression are secondary to those mentioned. These secondary manifestations are cyanosis, cold hands and feet, undernourishment, reduced blood pressure—usually 100 mm. mercury systolic and 80 mm mercury diastolic, pulse pressure of about 20 mm. mercury, pulsus paradoxus, low voltage of electrocardiogram, slurring of QRS complex, fixation of electrical axis, enlarged liver and spleen, hydrothorax, increased cerebrospinal pressure, edema of ankles, dyspnea on exertion, occasional mild polycythemia, and low plasma protein(10, 26).

Etiology. The formation of scar follows inflammation. The nature or etiology of the original inflammations is not always clear. Only occasionally is it due to a pyogenic infection. In one of my cases the scar developed after purulent pericarditis. In some instances the scar follows pericardial effusion. These scars are frequently of tuberculous etiology. In the majority of instances there is nothing in the history to indicate inflammation

Pericardiostomy. These patients are usually critically ill and they cannot stand deep anesthesia. Nitrous oxide and ether is recommended. In adults the operation might be done under local anesthesia. An incision about 8 cm. long is made over the left fifth costal cartilage and carried down to the cartilage. The perichondrium is cut and separated from the cartilage and the cartilage is removed usually from sternum to rib. The perichondrium is incised into the mediastinum. The internal mammary vessels are cut or not as desired. The pleural cavity is avoided. An aspirating needle is inserted into the pericardial cavity and as much pus is removed as possible. Then the pericardium is cut and the pus sucked out by a suction tube. The pericardial cavity is explored; any pockets of pus are opened. The cavity may be irrigated with physiologic solution of sodium chloride. One or two hundred thousand units of penicillin are placed in the pericardial cavity. The opening in the pericardial cavity need not be more than 2 inches. The parietal pericardium is sutured to the perichondrium and a watertight seal is made so that infection will not enter into the mediastinal space. A few sutures are placed between pectoral muscle and pericardium. Catgut is preferable to silk in the presence of infection. The skin is not sutured; but drains are not recommended. A large dressing is applied.

An oxygen tent is used if the patient is cyanotic. Large doses of penicillin are given intramuscularly and if desired applied locally as well as introduced into the pericardial cavity.

Irrigation of Pericardial Cavity. In some cases it might be desirable to irrigate the pericardial cavity with warm physiologic solution of sodium chloride. Dakin's solution or other irritants should not be used. If the pericardial cavity is irrigated through a catheter, care should be taken to make certain that the fluid escapes freely around the tube. Otherwise the heart will be compressed. The use of penicillin injected into the pericardial cavity is recommended. Large doses are tolerated—50 to 100 thousand units.

Prognosis. The mortality in cases treated by surgical drainage before penicillin became available was about 50 per cent; with the use of penicillin the mortality should be reduced considerably. One might also expect that aspiration of pus and introduction of penicillin directly into the pericardial cavity will make open drainage unnecessary in a high percentage of cases.

COMPRESSION SCARS ON THE HEART

The term constrictive pericarditis is usually used in the designation of this condition. Because the inflammation may be entirely absent in this condition and because the concept of compression ties in so well with our knowledge of the physiology of acute and chronic pressures on the heart, the term compression scar is preferable to the terms constrictive pericarditis and tamponade. These terms are now obsolete.

Compression scars can be produced by chemical irritants such as Dakin's solution in the pericardial cavity(23). Experimental material obtained in this way afforded opportunity to study the physiology of compression scars. The following points were established by these studies: 1, adhesions between heart and pericardium played no part in the etiology of compression scar;

of the sternal border. All structures are incised down to these costal cartilages. The third, fourth, and fifth costal cartilages together with about a centimeter or two of rib are removed leaving the perichondrium. The mammary vessels are preserved in some cases, but ligated in others. The intercostal bundles between third and fourth cartilages and between fourth and fifth cartilages are cut across. The pleural sinus is dissected laterally. The pericardial scar is wiped clean of loose tissues in every direction. The pleural cavity is usually opened and it is well to open it provided the anesthetist can take care of respiration. A large opening is preferable to a small sucking opening.

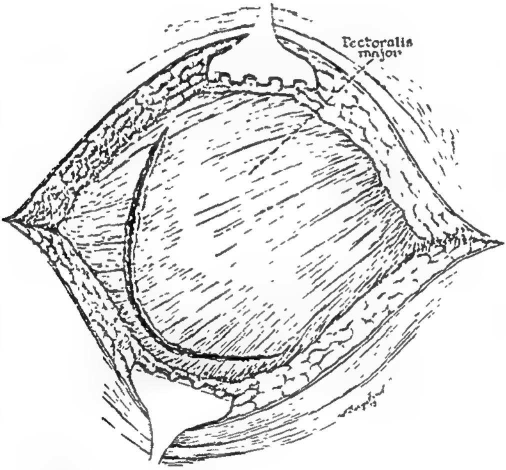


Fig. 2-14. Incision over precordium. The third, fourth, fifth costal cartilages are removed. (From Beck, C. S., and Griswold, R. A. Arch. Surg., 21 1064, 1930.)

More recently the author has used a different operative approach. A long transverse incision is made always below the breast. This incision extends from the sternal border to about the midaxillary line on the left side. The intercostal tissues between the third and fourth ribs are cut and the pleural cavity is opened widely. If necessary the sternum is cut transversely at the level of the third interspace and a self-retaining retractor is placed between the cut edges of the sternum. The internal mammary vessels are also cut and ligated on the left side and also on the right side if necessary. The third and fourth costal cartilages are also cut transversely. This provides an excellent exposure not only of the left side of the heart but also the right side as well. The bony framework is re-

or effusion in the pericardial cavity. The origin of the condition is obscure. It would appear that if bacteria were the cause of the inflammation the infection would produce pus. It would appear to be a nonsuppurating form of infection. The possibility of virus disease as etiology in some of these cases must be considered. It is possible that the majority of these scars follow invasion by a virus.

Treatment. The only treatment of these compression scars is operative. Palliation by diuresis is not the proper treatment. One would like the acute inflammatory stage to be over before the operation is performed and a period of several months might be necessary. Occasionally the process does not become quiescent. The patient continues to run fever, loses plasma protein, becomes emaciated. The writer operated on several such urgent cases and found tubercles in the scar. Some of these patients can be cured in spite of the acute condition. Others re-form scar and require repeated operation and some cannot be cured because the tuberculous process does not subside.

Preoperative Care. The operation should be delayed until the patient is afebrile and the acute or subacute nature of the inflammation has subsided. This may require months of waiting, during which time fluid is removed by tapping the abdomen and diuretics are used. Streptomycin should be given if the scar is tuberculous. A high protein diet is recommended. The patient should limit his fluid intake. Immediately before operation it is advisable to remove as much fluid as possible by tapping the abdomen and by use of ammonium chloride and mercupurin. Transfusion of blood is not done because the blood volume is already increased over normal. If the pulse rate is over 70 per minute in the presence of auricular fibrillation or auricular flutter it is advisable to give digitalis. Rarely will the mechanism revert to normal after operation if the patient had auricular fibrillation before operation. Quinidine is not effective in production of a normal mechanism. It is only the occasional patient who may require digitalis before operation.

Anesthesia. Nitrous oxide and ether is recommended. Cyclopropane is not recommended because the irritability of the heart is increased with cyclopropane and this, together with the operative handling of the heart at operation, may produce ventricular fibrillation. An intratracheal tube is not necessary. Mechanical respiration is an aid and should be used if a respirator is available Morphine and atropine are given before operation.

Position of Patient. *The patient is placed on his back in semirecumbent* position. Lights are arranged so that light will enter the wound below the second costal cartilage and also inferior to the sternum. Two beams of light are desirable.

Incision. The incision is usually on the left of the sternum although the writer has gone in on the right in cases in whom the compression scar was more on the right side of the heart than it was on the left. But exposure from the right is limited and my opinion is that a left approach is indicated in practically all cases. The incision is shown in Figure 2-14. It extends from above the third costal cartilage down over the third, fourth, and fifth cartilages. It curves laterally over the fifth cartilage almost to the anterior axillary line. The descending arm of the incision is about 3 cm. to the left

of the sternal border. All structures are incised down to these costal cartilages. The third, fourth, and fifth costal cartilages together with about a centimeter or two of rib are removed leaving the perichondrium. The mammary vessels are preserved in some cases, but ligated in others. The intercostal bundles between third and fourth cartilages and between fourth and fifth cartilages are cut across. The pleural sinus is dissected laterally. The pericardial scar is wiped clean of loose tissues in every direction. The pleural cavity is usually opened and it is well to open it provided the anesthetist can take care of respiration. A large opening is preferable to a small sucking opening.

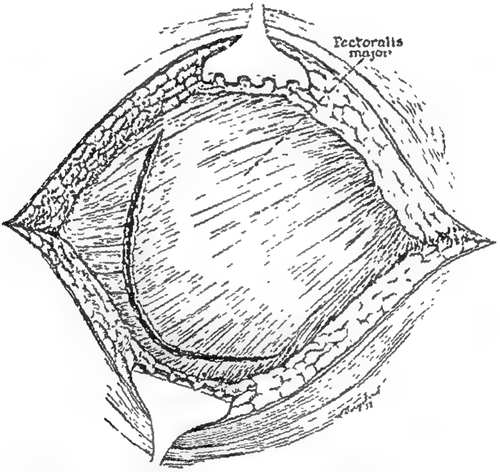


Fig 2-14 Incision over precordium The third, fourth, fifth costal cartilages are removed. (From Beck, C. S, and Griswold, R A. Arch. Surg, 21,1064, 1930)

More recently the author has used a different operative approach. A long transverse incision is made always below the breast. This incision extends from the sternal border to about the midaxillary line on the left side. The intercostal tissues between the third and fourth ribs are cut and the pleural cavity is opened widely. If necessary the sternum is cut transversely at the level of the third interspace and a self-retaining retractor is placed between the cut edges of the sternum. The internal mammary vessels are also cut and ligated on the left side and also on the right side if necessary. The third and fourth costal cartilages are also cut transversely. This provides an excellent exposure not only of the left side of the heart but also the right side as well. The bony framework is re-

paired by the use of wire sutures. This exposure does not call for the removal of any ribs or costal cartilages and requires no more time to make than does the procedure discussed above.

The anterolateral aspect of the scar is picked up in forceps and cut, care being taken not to cut heart and descending coronary artery. Clamps for traction are placed on the cut scar and separation of scar from heart is begun, care being taken to get into the proper plane of cleavage and not to enter myocardium and not to get between layers of scar. As a rule this can be done satisfactorily. The incision is carried up over the base of the heart, over the conus arteriosus, the left auricle and the aorta (Fig. 2-15).

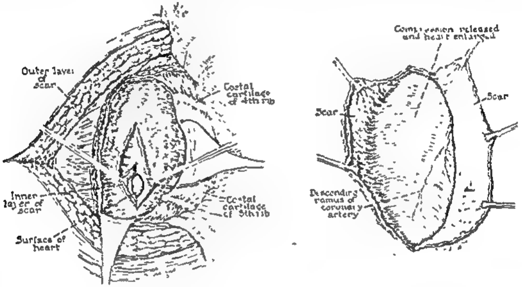


Fig 2-15 Left, scar is incised. Proper plane of cleavage is found. Right, scar is dissected from heart (From Beck, C S, and Griswold, R. A. Arch. Surg., 21:1064, 1930.)

The next step is lateral dissection of scar to the left. A right angle cut to the left is made in the scar above aorta and carried down toward the operator. The underlying left auricle and left pulmonary veins are carefully separated from the scar. The left phrenic nerve is dissected from the outside of the scar if this is possible, but if it is adherent in the cicatrix it is not disturbed from its bed and excision of scar goes down to phrenic nerve. Separation of scar from heart may be difficult. It is well to stay out of trouble by exercising every care in this dissection. In separating scar from the heart it may be helpful to make a pie-shaped incision in the scar. The rest of the operation is a continuation of this technic. The scar is resected on the left lateral margin down over apex of heart and to the diaphragm. The scar may be separated from the heart posteriorly by the finger if this separation is possible, but removal of posterior scar is not possible nor is it necessary The diaphragmatic part of the scar is separated from heart and removed.

The operator then takes the right margin of the scar in Kocher clamps. The right pleural sinus is dissected back. The dissection is carried up over the aorta and right auricle and superior vena cava. The triangular technic is a great aid. The scar is cut into pie-shaped pieces and excised. The right auricular ear can give trouble. Resection to the right is done as far as

feasible and as much scar is excised as can be done safely. The heart does not tolerate rotation and angulation for long periods of time and may require rest periods.

There are various technics for hemorrhage from the heart. If you encounter hemorrhage when the scar is cut, it is advisable to bring the scar back and over the bleeding area and carefully suture the scar to the underlying area (Fig. 2-16). Small needles and fine silk are used. Then incise around this area leaving a small graft of scar on the bleeding point. If the auricular ear is cut a hemostat can be placed on it and a ligature of silk applied. The auricle may be torn by a needle passed through it. As a rule there are no bleeding points from myocardium unless the operator cuts

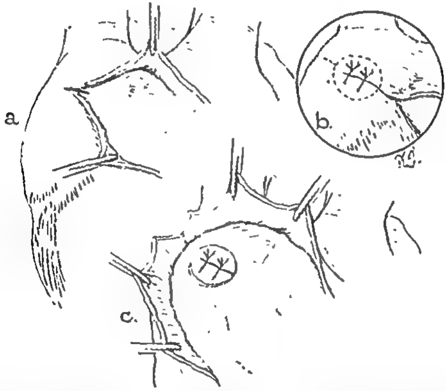


Fig. 2-16. The auricular wall may protrude into the area of dissection If the auricular wall should be cut in dissection of a scar from the auricle the wound can be repaired by a method shown in b and c. One or two silk sutures can be placed in the scar to close the auricular wound and the scar is cut around the sutures leaving a small graft of scar on this particular part of the auricle.

into it; this accident can readily occur, but should not be at all serious. Sutures plus a small muscle graft are helpful. The field is made dry. This might require an hour to accomplish but it is worth the time. Silver clips are valuable for hemostasis. The left pleura is opened widely for drainage and closure of the wound is carried out. A drainage tube is placed in the left chest through a separate stab wound This tube is connected to a water seal and kept in place for one or several days.

This operation requires three to four hours. It may be quite an easy operation to perform in some cases but in certain other cases it is the most difficult operation in the entire field of surgery.

After Operation. The patient is placed in an oxygen tent. The airway is sucked out. Transfusion of blood and intravenous fluid are not given.

These are contraindicated except in those patients in whom severe hemorrhage occurred. Morphine is given as indicated. Fowler's position is used after the patient recovers consciousness.

It is remarkable how well these patients get along. As a rule, the circulation improves during the operation after the heart is decompressed. The color improves. Pulse pressure increases. Not infrequently some improvement is lost after operation due to dilatation of the heart. Acute dilatation of the heart may cause death within the first 12 hours after operation. The treatment of acute circulatory collapse following operation is to remove 500 ml. of blood from the patient. This reduces venous pressure, reduces blood volume, and reduces the tendency of the atrophic heart to dilate after the compression agent has been removed.

Occasionally auricular flutter or auricular tachycardia develop after operation. For this complication digitalis is given. For acute conditions with a pulse rate above 120 to 130 per minute digitoxin 1.2 mg. is given intravenously. Lanatoside C (cedilanid) 0.8 mg. may be given intravenously for this complication. Satisfactory results have been obtained by the use of these drugs. If the condition is not of emergency nature, the patient should be digitalized in the usual way and kept on maintenance dose. If fluid collects in the chest it is removed by aspiration. Diuresis usually develops within a few days. The patient usually is ambulatory in two weeks.

Delayed Improvement. This occurs during several weeks or months after operation. It is due to recovery of myocardium from atrophy of disuse. Occasionally the retention of fluid persists until this improvement occurs. Venous pressure may remain elevated until this period is passed. The liver may remain enlarged due to fibrosis. In the majority of patients the degree of improvement is indeed remarkable. Complete cure in every way can be achieved.

Failure to Cure. While complete cure can be obtained in the majority of patients after operation, there are some failures. These are due to three considerations. One is an inadequate removal of the compression scar at the time of operation. The areas most frequently missed at operation are the conus arteriosus, pulmonary artery, aorta, right auricle, and also on each side of the heart. Emphasis should be placed upon decompression of the heart over its basilar portion. Partial operation yields only partial results. Operation should be such that failure to get a full cure cannot be blamed upon an inadequate operation. The second cause for failure to achieve full cure is due to extension of the extrinsic scar to involve the intrinsic substance of the heart. The scar invades myocardium. Myocardium may be replaced by calcified plaques extending the entire width of myocardium. As a rule, the scar remains extrinsic to the heart and the surgeon can see at operation that the myocardium is not seriously involved. The third cause of failure is re-formation of scar. This occurs in those patients in whom the inflammatory process is still active after operation. The patient may be improved temporarily but in the course of months is back where he was before operation. These are usually cases of tuberculous etiology. Other cases have gone on to develop miliary tuberculosis after several operations were done to remove scar. The scar may obliterate

anatomic parts of the heart as though it were poured in a liquid condition and then solidified. When recurrence follows two or three satisfactory operations the surgeon may lose his inclination to try again for a cure. The writer suggests that he should not give up but should do the operation again. I have had cure after the third attempt.

Preascitic Compression Scars. There are instances in which the contracture of the compression scar is not quite enough to produce ascites. These patients have venous pressures of 14 to 20 cm. water. In these mild forms of compression the heart does not completely fill with blood, the output of the heart is reduced and the patient has mild, persistent symptoms of compression. Medical measures do not cure the condition. An inert compression scar surrounds the heart and this organ is unable to take a normal beat. Diagnosis can be made with accuracy in these patients. Operation should always be done. The operation cures this condition.

Results of Operation. Up to 1949 the writer had performed 70 operations on 64 patients. The results are as follows: operative mortality (ventricular fibrillation) 1 or 1.5 per cent; postoperative deaths, from tuberculosis 5, other causes 5, making a total of 15.7 per cent; deaths occurring over a period up to 18 years, 5 or 7.8 per cent; total living—from several months to 18 years, 48 or 75 per cent, and of these there are 46 complete cures and 2 with some recurrence but who are improved. There was one operative mortality (1934) due to ventricular fibrillation from pressure on descending ramus of left coronary artery. This complication could be taken care of now but at that time there was no effective method of defibrillation. There were 10 postoperative deaths; 5 were due to tuberculosis, 2 were due to infection, and 3 were due to acute dilatation of heart. Perhaps the acute dilatation could have been taken care of by bloodletting. The 5 patients who died after discharge from the hospital were improved in so far as compression was concerned. One developed miliary tuberculosis and died several months later, one developed pneumonia several years later and died; one developed recurrence of compression and died several years later; two died of unknown cause. There are 48 living patients, and 46 are entirely free of ascites. Operation was not refused a single patient because of seriousness of physical condition.

Results of Heuer and Andrus(27) were as follows: operations done over a period of 5 years, 19 on 18 patients; of these 7 were cured; 3 recently operated upon were improved and probably cured; 5 were improved but not cured and 4 were not improved. Cure was obtained in 55 per cent of the patients.

Results by Harrington(28) were as follows: 24 patients were operated upon. Of these, 6 died in the hospital There was 1 operative death, 2 deaths due to tuberculosis and 3 due to cardiac failure following operation. Of the 18 remaining patients, 9 were cured and 9 have shown marked improvement following operation. Cure was obtained in 37.5 per cent of the patients. An excellent analysis of this subject by Chambliss appeared in circulation, 4:816, 1951.

These are contraindicated except in those patients in whom severe hemorrhage occurred. Morphine is given as indicated. Fowler's position is used after the patient recovers consciousness.

It is remarkable how well these patients get along. As a rule, the circulation improves during the operation after the heart is decompressed. The color improves. Pulse pressure increases. Not infrequently some improvement is lost after operation due to dilatation of the heart. Acute dilatation of the heart may cause death within the first 12 hours after operation. The treatment of acute circulatory collapse following operation is to remove 500 ml. of blood from the patient. This reduces venous pressure, reduces blood volume, and reduces the tendency of the atrophic heart to dilate after the compression agent has been removed.

Occasionally auricular flutter or auricular tachycardia develop after operation. For this complication digitalis is given. For acute conditions with a pulse rate above 120 to 130 per minute digitoxin 1.2 mg. is given intravenously. Lanatoside C (cedilanid) 0.8 mg. may be given intravenously for this complication. Satisfactory results have been obtained by the use of these drugs. If the condition is not of emergency nature, the patient should be digitalized in the usual way and kept on maintenance dose. If fluid collects in the chest it is removed by aspiration. Diuresis usually develops within a few days. The patient usually is ambulatory in two weeks.

Delayed Improvement. This occurs during several weeks or months after operation. It is due to recovery of myocardium from atrophy of disuse. Occasionally the retention of fluid persists until this improvement occurs. Venous pressure may remain elevated until this period is passed. The liver may remain enlarged due to fibrosis. In the majority of patients the degree of improvement is indeed remarkable. Complete cure in every way can be achieved

Failure to Cure. While complete cure can be obtained in the majority of patients after operation, there are some failures. These are due to three considerations. One is an inadequate removal of the compression scar at the time of operation. The areas most frequently missed at operation are the conus arteriosus, pulmonary artery, aorta, right auricle, and also on each side of the heart. Emphasis should be placed upon decompression of the heart over its basilar portion. Partial operation yields only partial results. Operation should be such that failure to get a full cure cannot be blamed upon an inadequate operation. The second cause for failure to achieve full cure is due to extension of the extrinsic scar to involve the intrinsic substance of the heart. The scar invades myocardium. Myocardium may be replaced by calcified plaques extending the entire width of myocardium. As a rule, the scar remains extrinsic to the heart and the surgeon can see at operation that the myocardium is not seriously involved. The third cause of failure is re-formation of scar. This occurs in those patients in whom the inflammatory process is still active after operation. The patient may be improved temporarily but in the course of months is back where he was before operation. These are usually cases of tuberculous etiology. Other cases have gone on to develop miliary tuberculosis after several operations were done to remove scar. The scar may obliterate

without drainage carried out. In some cases of tuberculous effusion the formation of fluid may subside and later on chronic compression of the heart may develop after the inflammatory stage is passed. These patients are given a period of rest for the acute stage to subside. When this occurs the compression scar is removed by operation.

The left fifth rib is removed through an incision about 8 cm. in length. The mediastinum is opened through the bed of the cartilage. The mammary vessels can be ligated or not as the operator decides. The parietal pericardium is opened and fluid is removed. A piece of pericardium should be taken for study. Exploration of heart and pericardial sac is carried out to establish etiology of the effusion. Neoplasm may be present. Tubercles may be found. The pericardium is sutured to the bed of the costal cartilage. The pectoral muscle and skin are closed by suture.

If fluid reforms in these cases tapping is carried out through the scar of the operation. In nontuberculous cases it might be desirable at the time of operation to open the left pleura and leave it open so that pericardial fluid can drain into the left chest from which it can be removed by tapping.

ADHESIONS TO THE HEART

Extrinsic deformities of the heart can disturb the circulation. Under this heading is grouped a variety of conditions that can be corrected by operation. The physiology of these conditions is based upon rotation of the heart, angulation of the heart and local pressure on the heart. The effect of these disturbances can be demonstrated in the experimental laboratory. They produce tachycardia, changes in arterial and venous pressures, and sometimes ventricular fibrillation. Rotation of the heart is especially harmful. It is interesting to note that traction in the long axis of the heart does not disturb the circulation. Local pressure disturbs circulation especially if pressure is applied to those areas where the intracardiac pressure is not high, such as auricles and right ventricle.

These physiologic disturbances are seen occasionally in patients. The term adhesive pericarditis was applied to pericardial lesions without definite knowledge of the way in which the circulation was disturbed. We now know that in most instances adhesions to the heart do not produce clinical symptoms and in those rare instances in which symptoms are produced the mechanism is by rotation and angulation. The Brauer operation of cardiolysis(29, 30) consisted in removal of the bony precordium to give a soft yielding chest wall for the heart to pull upon through adhesions. This operation was based upon fallacious reasoning and it is now recognized that in those instances in which benefit was obtained the good result was due to reduction of angulation and torsion rather than reducing the pull on unyielding chest wall. The operation should be directed more properly to freeing the heart by the removal of pericardium and restoration of normal cardiac position. These adhesions are the result of inflammation in pericardium and mediastinum. Tuberculosis, rheumatic fever, and other infections produce these adhesions(31). Artificial pneumothorax may accentuate dislocation of heart and accentuate circulatory symptoms. In one instance the writer found the ventricles of the heart herniated

PERICARDIAL EFFUSIONS: STERILE, HEMORRHAGIC, TUBERCULOUS, NEOPLASTIC

These different types of effusion are grouped together because the treatment is the same in each. These effusions produce compression of the heart. Treatment consists in evacuation of the fluid. In contrast to purulent effusions, open drainage to the outside is not the method of treatment. In these conditions fluid is removed by aspiration or by operation without drainage to the outside.

Recognition of these conditions is based entirely upon the signs of cardiac compression produced by the fluid. This subject is discussed elsewhere. It should be pointed out that the pericardial sac may or may not stretch in response to the fluid within it. In some instances the sac enlarges readily so that a large quantity of fluid is in the sac. In other instances the sac does not enlarge and severe compression can be produced by 350 ml. of fluid. These variations should be considered in diagnosis. Removal of fluid does not treat the underlying condition producing the effusion. It treats only the compression of the heart. Fluid is removed either by aspiration or by pericardiotomy.

Aspiration. In many instances fluid can be removed satisfactorily by aspiration of the pericardial sac. One does not like to insert a needle into a large cardiopericardial structure because this structure may be a large dilated heart instead of a small compressed heart surrounded by a large buffer of fluid and the needle might tear auricle, ventricle, or coronary vessel. If this accident should occur, exploration and repair of the wound should be carried out.

Fairly strong suction may be desired. An 18 or 20 gauge needle attached to a 20 or 50 ml. glass syringe is used. If fluid runs freely a rubber connection and suction bottle are desirable. Various sites for tapping have been recommended. Two structures to be avoided are the internal mammary vessels and the pleural sinus. The mammary vessels lie 2 or 3 cm. lateral to the edges of the sternum. The pleural sinus lies farther laterally and in the presence of effusion with a dilated pericardium the pleural sinus is displaced to the side so that there is sufficient space to introduce the needle. The space between the fourth and fifth cartilages is satisfactory. The needle is introduced straight in. The distance between skin and pericardium is about 5 cm. Anything beyond this should bring the end of the needle inside the pericardial cavity. Bloody fluid does not necessarily mean that the needle has penetrated the heart. Many effusions are bloody. Sometimes you can feel the heart scrape against the needle. As much fluid is removed as possible. Studies of the fluid should be done to establish diagnosis. Injection into a guinea pig is frequently indicated for diagnosis of tuberculosis. Cultures, smears, and cell counts should be done.

Pericardiotomy. There are instances in which fluid cannot be removed successfully by aspiration because the fluid contains particles of fibrin or the fluid is thick. Diagnostic taps establish the diagnosis of fluid. In several cases of pericardial effusion the writer carried out exploration and established the diagnosis of neoplasm in heart and pericardium. Operation may be indicated in tuberculous effusions. Fluid is removed and closure

are going to break open. It is obvious that some reinforcement of the wall of the aneurysm would be beneficial and the writer(32) has done an operation for this purpose (Fig. 2-18). In this case a graft of fascia lata was used to reinforce the aneurysm. This operation may find application to certain patients. Frequently the degenerative changes in the heart are severe so that operation may not be indicated, but there may be other instances where a graft would support the heart and prevent rupture of the aneurysm. The writer has tried to make aneurysms of the heart experimentally by crushing myocardium but this attempt has not been successful.

OPERATIONS FOR CORONARY ARTERY DISEASE(33, 34, 35, 36)

Experiments were carried out by Beck and his associates for the purpose of improving the blood supply to the myocardium. Approximately 4,000 to 5,000 experimental operations were done in the past 22 years. Emphasis is placed upon the fact that the coronary vessels were dealt with directly. This direct approach merits comment because it yielded information concerning coronary artery disease which could not be obtained in any other way. This direct approach to the coronary problem has more to offer than any other method of study with the possible exception of prevention of the disease itself. Certain facts were established by this vast amount of direct experimentation. In order to understand and accept these facts it is necessary to have a prepared attitude of mind. If anyone believes that surgery has no place in the treatment of coronary artery disease then none of these facts established by experimentation can be accepted and applied to the treatment of the disease. If one has a prepared attitude of mind then these facts are acceptable.

Axioms—The New Look. 1. Surgical operation cannot stop the occlusive process in the coronary arteries and cannot cure the disease.

2. Surgical operation cannot restore degenerated myocardium and cannot be effective in severe degeneration of heart muscle. Patients in failure from severe degenerative disease, therefore, are not acceptable candidates for the operation. The type of death produced by degenerative disease may be referred to as muscle death.

3. Coronary artery disease may be static for a period of months or years. In this event comparison of the preoperative condition with the postoperative condition indicates the effect of the operation.

4. Coronary artery disease may be progressive. Progress of the occlusive process may overtake benefit from operation. The following hypothesis is tenable provided the assumption is made that surgical operation can improve the coronary circulation. Let us assume that operation improved the circulation by 50 undefined points. Clinically the patient is better. The occlusive process then progresses for a loss of 65 points. Now the patient is worse than before operation. It is possible that this loss would have killed the patient were it not for the operation. Therefore, it is possible for a patient to be worse off clinically after operation yet the operation saved his life.

5. The occlusive process may progress and kill the patient without negating the beneficial effect of operation.

through an opening in the pericardium. The ventricles were compressed and almost strangulated in this defect. In another instance of cardiac adhesions tachycardia and syncope were produced by hyperextension of chest. These symptoms were relieved by bending forward and were cured by operation.

ANEURYSM OF HEART

Most aneurysms of the heart occur as a result of coronary artery occlusion. The myocardial infarct produces a cicatrix which stretches in response to intracardiac pressure. When examined under the fluoroscope the aneurysm fills out as the heart goes into systole and a paradoxical appearance is obtained (Fig. 2-17). Some of these aneurysms look as though they

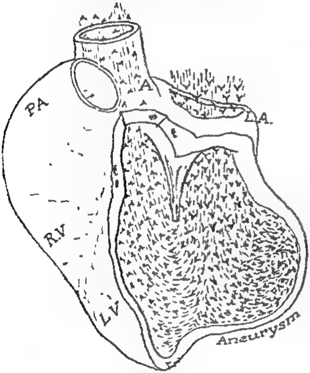


Fig. 2-17. Hemodynamics in presence of aneurysm. Blood escapes into the aneurysm during systole instead of being expelled into the aorta. (From Beck, C. S. Ann. Surg., 120:34, 1944.)

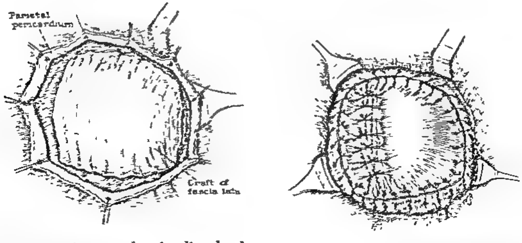


Fig. 2-18. The parietal pericardium has been cut around the base of the aneurysm A graft of fascia lata is placed over the aneurysm and sutured to parietal pericardium. The graft is tightened by additional sutures to reduce the size of the aneurysm. (From Beck, C. S. Ann. Surg., 120:34, 1944.)

nificance of this finding is that the presence of intercoronaries made it possible for the heart to continue to function thus providing time for the occlusive process to become complete. This conclusion is well supported by experiment. These authors found that intercoronaries were present less frequently in specimens in which the occlusive process was complete and acute. My interpretation of this is that the intercoronaries developed less rapidly than did the occlusive process. And they could not keep up to the occlusion. If there had been a better development of these channels then the occlusive process would have been given time to become chronic. These authors found intercoronary channels present in 9 per cent of specimens without coronary disease. We found variations in dogs and no doubt the specimens with them survived test ligation of a major artery and those without them did not survive ligation of the artery. The same probably applies to the human patient.

Methods by Which Coronary Circulation Can Be Improved. There are two methods by which the coronary circulation to the myocardium can be improved. One is by the addition of blood from outside sources, and the other is by a more even distribution of the blood that goes through the diseased coronary arteries. It is possible to add new blood to the heart but it is no easy accomplishment. Most methods that have been studied have fallen short of expectations. Blood can be added to the heart by way of grafting tissues to the heart that possess an outside blood supply. Connections between the graft and the heart are expected to occur in these graft operations. Various tissues have been used for this purpose. Blood can also be added to the heart by changing the venous system into an inflow channel. This method also has certain limitations. A more even distribution of blood that goes through the diseased coronary arteries can be more readily accomplished. On the basis of experimental work two operations for coronary artery disease were developed in our laboratory. These are known as the Beck I operation and the Beck II operation.

The Beck I Operation. This operation consists of the following technics: 1, abrasion of the epicardium and parietal pericardium by a metal burr; 2, partial occlusion of the coronary sinus; 3, application of inflammatory agent (0.2 gm. of powdered asbestos) to the surface of the heart; and 4, application of parietal pericardium and mediastinal fat as grafts to the surface of the heart.

The heart is exposed by an incision between the sixth and seventh ribs. The patient is placed on the operating table with the left side up. Intratracheal anesthesia is used. I always use the Wolfe-Rand mechanical respirator. This respirator has given us very satisfactory results. The pericardium is opened along the left phrenic nerve. A ligature is passed around the coronary sinus close to the point where it enters the right auricle. Some practice on the dead heart is desirable in order to place this ligature properly. The needle is passed along the wall of the sinus directly into the left auricle from below upward and comes out through the auricle just superior to the sinus. The next step is to abrade the surface of the heart. This is done carefully and gently. Xylocaine or 1 per cent procaine is dropped onto the surface of the heart to reduce its irritability before the

6. Other causes of death do not negate the beneficial effect of operation.

7. The trigger mechanism must be accepted in this new attitude. A trigger is an ischemic area of myocardium which becomes an ectopic center for impulses from the myocardium and which in turn destroys the coordinated mechanism. The myocardium becomes convulsive and this kills. This type of death is referred to as *mechanism death* in contrast to *muscle death*.

8. The destructive property of a trigger can be increased or reduced by as small a quantity of blood as 1 to 5 ml. per minute. This has been established by experiment.

9. Surgical operation is beneficial if it can supply from 1 to 5 ml. of blood per minute to an ischemic area. To be beneficial it is not necessary for surgical operation to produce "a new set of coronary arteries." The requirements for benefit may be small in terms of blood.

10. Mechanism deaths may occur in the absence of any new or recent anatomic lesion in the heart, either in the coronary arteries or in the muscle. In these patients the heart had the potential for continued function. The absence of recent pathology in arteries and myocardium was reported by Blumgart(37). Yater(38) found that the specimens in one third of all victims of coronary artery disease showed no myocardial infarcts, either old or recent. This group of patients could be protected by operation provided the operation was done before death. There is another group of patients with infarct who develop mechanism death. In these patients the heart had the potential for continued function. It is possible to improve the coronary circulation in these patients.

11. The coronary circulation should be considered on the basis of a, total inflow: and b, distribution of the blood that goes through the diseased arteries. The heart can maintain function on a small fraction of normal total inflow. In the dog the beat was maintained by only the septal artery or by 1 mm. lumen of the circumflex artery. In the human a number of specimens have been found in which all coronary inflow was occluded and in many specimens a hairlike lumen was found in the major arteries. In order for these severe reductions in inflow to take place it was necessary for the heart to possess a functional system of intercoronary arterial channels so that the blood was evenly distributed. Without an even distribution the occlusive process kills by destruction of the mechanism. If the mechanism is not destroyed then the heart carries on until the occlusive process becomes severe or complete and results in muscle death. One purpose of operation is to prevent mechanism death. If this can be accomplished then muscle death may take place. In making this substitution the patient is given time for the development of additional occlusions. The substitution of one type of death for the other type of death requires time which for the patient means extension of life.

Zoll, Wessler, and Schlessinger (39) reported that intercoronary arterial channels were found in every heart in which a major coronary artery was completely and chronically occluded. That intercoronary arterial channels were present in every such specimen is no mere coincidence. The sig-

the dog because the veins thicken and some of them become occluded. While these changes are taking place in the veins intercoronary communications develop and, in the dog, these provide protection later on. It is probable that the mechanisms of benefit in the human are the same as in the dog but at the present time this point has not been established by examination of human specimens.

Selection of Operation. Both of these operations are beneficial. However, the Beck II operation is more difficult to do and requires two stages. If work in the future will show that the simpler operation can give almost as much benefit as the more complicated operation, preference will be given to the simpler procedure. A final statement cannot be made at this time.

Results on Patients. Thirty-seven patients were operated upon by the Beck I operation prior to 1942. These patients were studied by Feil. Since 1945, approximately 125 patients were operated upon using either the Beck I or the Beck II procedure. The clinical results of these two operations are approximately as follows:

In those patients who received the Beck I operation the results were excellent or good in 64 per cent, a fair result was obtained in 18 per cent, and the result was unchanged in about 18 per cent. In the patients who received the Beck II operation the result was excellent or good in 92 per cent and it was classified as fair in 8 per cent. The definition of excellent is: *no pain, no medicament, and return to former employment*. The definition of good is: occasional pain, occasional nitroglycerin pill, and return to former employment.

A critical analysis by Feil of the results on patients operated upon at the University Hospitals of Cleveland shows that approximately 85 per cent of the patients received an excellent or good result. This analysis was of patients who had a patent graft. This means that the vast majority of the patients with coronary artery disease who go through the operation satisfactorily will be completely or partially relieved of pain and will be able to return to their former employment. We would expect these clinical results to be as good as they are on the basis of the experimental work on dogs.

Mortality. In the past two years the mortality during operation or in the hospital after operation was about 20 per cent. No doubt the mortality could be reduced by selection of patients who had less severe disease. With proper selection of patients it might be possible to reduce the mortality to about 5 to 10 per cent. Several patients who would have been accepted for operation died in the preoperative period in the hospital. The mortality in these patients without operation is high. Lindgren(40) published figures on patients who were investigated for sympathectomy for angina pectoris. There were 88 patients who were acceptable for operation but operation was not done. The mortality was 17 per cent the first year and 13 per cent the second year, a total two-year mortality of 30 per cent.

Selection of Patients for Operation Diagnosis should be made by an experienced cardiologist. In our series of cases we made every attempt to have a correct diagnosis Granted that the patient has coronary artery disease the next question is whether operation should or should not be carried out on any given patient. No patient was accepted within six months of an infarct. This provided time for intercoronaries to develop because of the occlusion. There

operation is done. The heart should not be dislocated during the process of abrasion. The lining of the parietal pericardium is abraded thoroughly everywhere. Then the powdered asbestos is sprinkled over the entire surface of the heart. The strand of ligature material around the sinus is then picked up and tied around the sinus plus a stilet measuring 2.5 mm. in diameter. The stilet is then removed. This produces partial occlusion of the sinus. The pericardium is then closed loosely and deposits of mediastinal fat are brought into contact with the heart as much as possible. A drainage tube is used. The ribs are approximated with several wire sutures. The soft parts are closed with silk.

The patient is placed in an oxygen tent after operation. Routinely I digitalize all patients before and after operation on the heart. It is my belief that digitalis reduces the tendency for ventricular fibrillation. The anesthetic we use consists of intravenous administration of pentothal together with the administration of nitrous oxide and curare. After the patient is anesthetized the nitrous oxide is switched to ether. Light anesthesia is used on all patients.

Benefits Produced by the Beck I Operation. Experimentally we have shown that this operation protects the life of the dog after a major coronary artery is occluded. The operation also reduces the size of the infarct after a major coronary artery is occluded. The operation does not give complete protection when such a large artery as the circumflex ramus or the descending ramus is occluded in one step. After ligation of the descending ramus the mortality is reduced from 70 per cent to approximately 27 per cent and the size of the infarct is reduced by about 60 to 70 per cent. Most of this protection is afforded by intercoronary channels but in some of the experiments anatomic communications were demonstrated between the heart and grafts, and it is possible that some outside blood was added to the heart.

The Beck II Operation. The Beck II operation consists of introducing red blood into the coronary sinus. This is done either by placing a small vein graft (taken from the patient's elbow before operation) between the aorta and coronary sinus, or by direct anastamosis between these two structures. The technic for doing this will not be described. In order to do it it is necessary to practice the operation on dogs. Two to three weeks later the coronary sinus is partially occluded as described in the Beck I operation. The pericardium is loosely closed The incision, closure, and anesthesia are the same as in the Beck I operation.

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from the hospital. There were 2 deaths in the last 49 consecutive operations of the Mount Sinai Hospital of Cleveland(51).

The late mortality subsequent to discharge from the hospital was as follows: from discharge up to 1 year, 9 deaths in 146 patients, or 6.6 per cent; from 1 year up to 2 years, 4 deaths in 83 patients, or 4.8 per cent. The total mortality was thus 11.4 per cent.

If the hospital mortality of 6.6 per cent is added to the later mortality of 11.4 per cent, the total two-year mortality amounts to 18 per cent. This figure may be compared to the two-year mortality of 30 per cent in Lindgren's series of patients already referred to.

	Patients	Deaths	Per Cent	
Hospital mortality	75	5		6.6
Later mortality				
From discharge to 1 year	146	9	6.6	
From 1 year to 2 years	83	4	4.8	
			11.4	11.4
Total 2-year mortality				18.0

OTHER OPERATIONS FOR CORONARY ARTERY DISEASE

Fauteaux Operation(41). This operation consists in ligation of the magna cordis vein which is the main tributary of the coronary sinus and pericoronary neurectomy. This operation is based upon experimental studies. Removal of tissue at the base of the aorta and around the left coronary artery is referred to as pericoronary neurectomy. Both vagus and sympathetic fibers are resected.

Sixteen patients with coronary disease were operated upon. There were three postoperative deaths and two deaths occurred subsequently. The results in the patients still living seem to be satisfactory.

It is the opinion of this writer that this approach to this subject merits further investigation and study. All surgical attempts to increase blood supply to the heart should be encouraged. The coronary artery problem is quite as important as the cancer problem.

Recently Leighninger has studied the subject of retrograde blood flow in the coronary arteries following resection of the sympathetic and vagus nerves. This study was done in the following way: the circumflex artery was ligated at its origin. The distal end of the artery was cannulated and the amount of retrograde flow per minute was measured. This unpublished study by Leighninger did not show any significant differences in retrograde flow following resection of these nerves and threw doubt upon the assumption that sympathectomy increases the blood flow to the heart.

The Vineberg Operation(42). This author has attempted to use the internal mammary artery as a source of additional blood supply to the heart. The internal mammary artery is dissected out, ligated, and cut across. The sixth intercostal branch of this artery is also cut across but it is not ligated. A tunnel is then made by means of a clamp under the epicardium of the left ventricle. The internal mammary artery with its patent inter-

are certain patients who should not be accepted for operation. We have learned by experience not to accept patients who have myocardial failure. These patients are going to die regardless of operation and operation can scarcely be expected to help them after they have advanced to the point of failure. We believe that patients with severe enlargement of the heart should not be accepted for operation. In these patients the heart may be giving way and operation will not stop the progress of the disease. Serious complications such as cerebral arteriosclerosis and serious disease in the aorta and in the vessels to the legs contraindicate operation. Progressive disease in the coronary arteries is also a contraindication to operation. Progressive disease in a young person is serious; it accounted for three of our operative deaths. We feel that the chronologic age of the patient is less important than the tissue age, and a man of 66 might be a better candidate for operation than a man of 56 years. We have accepted patients with status anginosus and some of these patients have returned to work following operation. We prefer the patient to have anginal pain rather than not to have it. I operated upon several patients without pain but with severe degenerative disease in the heart. The reduction of pain after operation is a nice indication of result.

It is my opinion that surgical operation will find its greatest application to patients in the early stages of coronary disease rather than in the late stages of coronary artery disease. Facts established by experiment indicate that if the operation is performed early it will protect the patient against the possibility of mechanism death. Furthermore, if the operation is done early the risk is considerably reduced. If surgical operation provided nothing more than the development of intercoronary arterial channels it would be beneficial. My impression of the studies by Zoll, Wessler, and Schlessinger(39) is that if these intercoronary channels are present the disease process is given time to progress to the point of chronic and complete occlusion of a major artery before death occurs. If these channels are not present then death occurs earlier in the course of the occlusive disease. These authors showed that intercoronary channels were present in 9 per cent of the normal hearts It is probable that patients with intercoronary channels make a better recovery after coronary artery occlusion.

ADDENDUM

Since this chapter was written additional results from the Beck operations have been compiled which should be added to this discussion. Evaluation of 103 patients 6 months after operation showed that 90 per cent were improved with respect to pain (45 per cent had no pain, 45 per cent had less pain) and 90 per cent were improved with respect to ability to work (35 per cent were better able to work without limitation, 55 per cent were better able to work with some limitations).

In the period from January 1, 1954 to May 6, 1955 a total of 75 patients were operated upon using the Beck I procedure. In this group there were 2 deaths from thoracotomy alone and 3 deaths either during or soon after operation, a total mortality of 6 6 per cent One patient died after discharge

the lungs. Complete occlusion of the artery is not tolerated for periods longer than one or two minutes. The incision in the artery is closed by sutures.

It is also possible to enter the pulmonary artery by way of the right ventricle. This method has been referred to by Neuhof(47) but it has not been satisfactorily developed. It offers better opportunity, in the opinion of the writer, than does the approach through the artery itself. Incision can be made in the wall of the right ventricle, the opening being controlled by the method of Beck (Fig. 2-7). A suction tube with suction turned off can be introduced through the opening into conus arteriosus and pulmonary artery. Suction is then turned on as indicated and both right and left pulmonary arteries are sucked free of clots. In this way the circulation is not completely stopped at any time.

Fig 2-19 *Fibroma arising from auricle and obstructing the middle orifice. Surgical methods* will be developed for removal of tumors such as this. Case of Houck and Bennett. (*From Houck, G H*, and Bennett, G. A Am Heart J., 5:787, 1930.)

Nicoll(48) found only 10 cases of successful Trendelenburg operations for pulmonary embolism in the world literature and reported the eleventh case in 1945.

TUMORS OF THE HEART

This subject is discussed because a beginning has been made in the surgical removal of these tumors Tumors of the heart appear to be rare but incidence will increase after methods for removal are developed.

These tumors can be classified as 1, pericardial; 2, cardiac; and 3, intracardiac. They are usually metastatic but some tumors are primary. Sarcoma and carcinoma of the pericardium and of the surface of the heart usually are associated with fluid in the pericardial sac. Sometimes this fluid is blood. Pressure on the heart may produce death.

costal branch is then drawn into this tunnel of myocardium and fixed into position by sutures. The author claims that a process of budding takes place from this transplanted artery and that transfer of blood to the heart occurs. Vineberg applied this operation to human patients with satisfactory results. Details of these experiences cannot be given at this time.

The Thompson Operation(43). This operation consists in the application of magnesium silicate powder (U.S.P. Talc) into the pericardial cavity. The fifth costal cartilage on the left is removed, the pericardium is opened, 2 to 4 drachms of magnesium silicate powder are applied to the surface of the heart. The term cardiopexy is applied to this operation. A quotation from Thompson's article is as follows:

"For a group of patients who were medical failures, this operation has produced most satisfactory results. It should be emphasized that almost all of the patients were terminal cardiac cases and more or less completely incapacitated. Few of them were satisfactory as surgical risks. As a result of the operation we were able to rehabilitate these patients so that 90 per cent of them were improved more than 50 per cent, and 40 per cent are more than 75 per cent improved.

"In addition to their physical improvement, the patients who later on died, lived an average length of life after the operation of five years, giving them an average life span of nine and one-half years from the onset of the first symptoms. We do not believe that these patients would have survived this length of time without the operation."

PULMONARY EMBOLECTOMY

In recent years considerable progress has been made in the prevention of pulmonary embolus. Several preventive measures have been taken. One of these is the use of heparin(44) and dicumarol(45) as anticoagulants. These agents have been used also as routine measures following operations. Ligation of veins in presence of phlebothrombosis has also been effective in prevention of pulmonary embolus Early ambulation of patient after operation, careful technical surgery to reduce trauma to a minimum, avoidance of dehydration, and avoidance of constricting dressings are other factors in the incidence of pulmonary embolus.

These various measures to prevent pulmonary embolus have proved to be valuable What is to be done for those patients who develop a pulmonary embolus? Many of these patients recover after the embolus develops but all of these patients do not recover It would be desirable if this latter group of patients were given the benefit of surgical removal of the embolus. The technical aspects of this problem are not so difficult as to forbid operation. However, little progress has been made in this direction

Removal of Pulmonary Embolus. A transverse incision is made over the left precordium The fourth and fifth costal cartilages are removed. Pericardium is opened. Trendelenburg(46) advised the use of a rubber tube under the pulmonary artery for traction and then opening of the artery parallel to its axis. He removed the embolus by means of a clamp. A glass suction tube may be used to suck out the clots. A clamp may be placed on the pulmonary artery to close incision and to allow blood to pass into

the lungs. Complete occlusion of the artery is not tolerated for periods longer than one or two minutes. The incision in the artery is closed by sutures.

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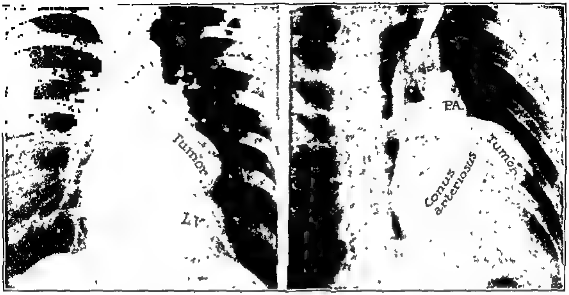

Fig 2-20 Calcified tumor of the left ventricle. Right, the right side of the heart is well visualized (From Beck, C. S Ann. Surg., 116:161, 1942.)

Fig. 2-21. Intrapericardial dermoid that eroded through the chest wall. Completely removed by operation (From Beck, C S. Ann Surg , 116 161, 1942.)

The writer has explored several patients with reticular cell sarcoma of the pericardium. Fluid was removed; biopsy was taken; pericardial sac was opened so that it communicated with the pleural cavity. Deep x-ray therapy was given. The results were favorable. This form of treatment is advocated by the writer.

If the tumor protrudes into the cavities of the heart, tumor cells may be seeded throughout the body. Some tumors are pedunculated and benign fibromas or myxomas that no doubt could be removed by operation (Fig. 2-19). Operative methods for this should be developed. The writer(49) successfully removed a calcified tumor of the left ventricle (Fig. 2-20). This tumor lay between the descending ramus and the circumflex ramus of the left coronary artery. It was completely removed.

Several dermoid tumors inside the pericardium have been reported. The writer successfully removed one of these as shown in Figure 2-21.

Recently Bahnson and Newman(50) partially removed an intracavitary myxoma of the right atrium. The two venae cavae were occluded for one minute while the auricle was opened and while the tumor was partially removed. The patient died in the postoperative period. No doubt these intracavitary tumors will appear more frequently now that surgical technic is developing to the point where intracardiac operations are possible. The heart pump of Gibbon or the use of hypothermia should aid in making this surgical development possible.

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3

CONGENITAL MALFORMATIONS OF THE HEART AND GREAT VESSELS

JOHN H. GIBBON, JR., AND HANS C. ENGELL

The remarkable developments in surgery of the heart and great vessels during the past 15 years have resulted from the cooperation among cardiologists, surgeons, and anesthesiologists. This cooperation has brought increased knowledge and progress to each of these specialties and must continue lest the results be marred by too many exploratory procedures and an unjustifiably high mortality rate. Technically, cardiac surgery presents no difficult problems to surgeons familiar with intrathoracic procedures. Therefore, to what extent cardiac surgery can be performed successfully, outside of the more highly specialized clinics, will depend on the experience of the attending cardiologist and radiologist and on the possibility of obtaining satisfactory anesthesia. The indications and technic for many cardiovascular operations are changing and increasing knowledge and experience will undoubtedly continue to change many concepts now held.

Indications for Operation. When a diagnosis has been established, the question arises whether the condition of the patient and our present technical resources justify an immediate operation, or whether it might not be more judicious to postpone operation for some years until increased knowledge will allow a safer, and more definitive, correction of the existing defect. It is preferable not to operate upon children under the age of two years. However, there are numerous exceptions to this general rule. Anomalies of the aortic arch and great vessels compressing the trachea or esophagus should be operated upon as soon as they are diagnosed The same holds true for a large patent ductus arteriosus, or a coarctation of the aorta, when these conditions result in intractable cardiac failure in the first year of life. However, the optimal age for most operative procedures for congenital malformations lies between the sixth and twelfth years when the *children are* of sufficient size to facilitate the surgical procedures and to allow utilizing the available diagnostic procedures to their full extent. Postponing operation too long may increase the amount of irreversible cardiac damage consequent to the malformation. Furthermore, after the age of adolescence degenerative tissue changes frequently take place; a patent ductus arteriosus may become more rigid, and possibly calcified, making the vessel wall *more friable* and operation more hazardous. The same holds true for the aortic wall in coarctation

If female patients with isolated septal defects or coarctation of the aorta [illegible] ieir defect, they tolerate [illegible] coarctation (8, 37). On the other hand a patent ductus arteriosus will *give rise to* or aggravate exist-

ing cardiac symptoms during pregnancy(18, 27). A patent ductus should, therefore, be operated upon promptly, if diagnosed in the early months of pregnancy.

Preoperative Care. It is important that all patients, and especially children, should be admitted to the surgical service at least 48 hours prior to the time of operation. It is important for the postoperative management that the patient should have time to become accustomed to the new surroundings and people. Respiratory exercises should be instituted and their importance explained to the patient before operation. Prophylactic antibiotic treatment also should be started.

Anesthesia. Only anesthetic agents with the least effect on cardiac function and blood pressure should be used. Adequate pulmonary ventilation must be maintained throughout the operation in order to avoid respiratory acidosis from the accumulation of carbon dioxide. Rapid induction, which in a few minutes will bring the patient to a level of anesthesia where it is both possible and necessary to intubate is to be deplored. If intubation, under such circumstances, takes one minute more than calculated, the result may be anoxia and cardiac arrest. Ether oxygen anesthesia with a closed rebreathing circuit still appears to be the anesthesia which gives the greatest margin of safety and the least disturbance to cardiovascular function. Cyclopropane has been widely used in thoracic surgery. It is not irritating to the lungs and permits rapid changes in level, but it has a narrow margin of safety and may cause cardiac arrhythmias. For the latter reason, it is not considered desirable for cardiac surgery.

In patients with congenital heart disease, where the maintenance of intact respiratory and circulatory functions is complicated by so many partly unknown pathophysiologic factors, Beecher's warning(3) against the use of multiple anesthetics still holds true: "When many agents are used, a difficult job becomes impossible. And when an accident occurs under such circumstances it is usually impossible to discover which agent was responsible. So experience can tell but little and errors are perpetuated."

Thoracotomy. For operations on the heart and great vessels, three types of thoracotomy are customarily employed: anterolateral, trans-sternal, and posterolateral. In the first two the patient is in the supine position and in the third the patient lies upon the side.

In the anterolateral approach the side operated upon is slightly elevated. The incision is made from the sternal border to the posterior axillary line over the third or fourth interspace. The pectoral muscles are divided over the rib below the interspace to be entered in order to permit a more secure closure. Division of two costal cartilages cephalad to the interspace used provides good exposure when the rib spreader is in place. The cartilages should be cut obliquely from without and medial to within and lateral. The oblique cut provides a broader surface for accurate firm approximation in closure.

A trans-sternal incision dividing the sternum at the level of the fourth interspace and entering both pleural cavities through both the right and left fourth interspaces provides excellent exposure to both sides of the heart and all the great vessels. The sternum should be cut obliquely from without

and cephalad to within and caudad to aid closure of the wound, as described above for the divided costal cartilages. A rib spreader between the divided sternal ends elevates the cephalic half of the sternum and upper ribs to provide an excellent operative exposure. Closed tube drainage of both pleural cavities should be established through separate stab wounds when the trans-sternal approach is used.

The posterolateral approach consists in the conventional periscapular incision with subperiosteal resection of the fourth or fifth ribs in adults and an incision through the fourth interspace in children. Because the supine position interferes less with cardiorespiratory functions, especially pulmonary ventilation, anterolateral or trans-sternal incisions are used for most operations on the heart and great vessels. The posterolateral incision, however, should always be employed for operations on coarctation of the aorta and whenever a very wide exposure of one side of the mediastinal structures is desired.

When a rib has been resected the periosteum of the resected rib should be accurately closed with continuous fine catgut sutures or interrupted nonabsorbable suture material. When an intercostal incision is utilized the ribs are approximated with pericostal chromic catgut sutures. The remaining layers are closed anatomically by interrupted fine cotton or silk sutures. Meticulous closure of the thoracic wall is important to diminish postoperative pain and to insure rapid and complete restoration of arm and chest function.

After most thoracotomies for cardiac or vascular operations closed drainage should be established through a rubber tube inserted through a stab wound in the sixth or seventh intercostal space in the midaxillary line. The rubber tube is connected to a trap bottle to collect the drainage fluid. The trap bottle is in turn connected to a water seal as soon as the thorax is closed. Provided there are no pulmonary air leaks, it is unnecessary to provide continuous suction.

Postoperative Management. During the recovery period the patient should be under continuous observation. Pulse, blood pressure, and respirations are recorded every 15 minutes until the readings become constant and every half hour or hour thereafter for the first 24 hours. The drainage bottle should be graduated so that the serosanguineous drainage through the chest tube can be measured at all times. Though the patient may be restless during recovery from anesthesia, analgesics or sedatives should not be given before consciousness is regained because depression of the respiratory reflexes is undesirable. Thereafter, small doses of morphine, or demerol, every fourth hour are preferable to larger doses at longer intervals. The objective is to relieve pain without depressing the cough reflex.

During the recovery period, and the first few postoperative days, the patient needs help to keep the airways free from accumulating secretion. Several times a day, respiratory exercises are carried out. The patient is instructed to use all his respiratory muscles in the manner practiced before the operation. The assistant places his hand symmetrically on both sides of the chest and exerts a moderate though firm, rhythmic pressure [illegible] time with the expirations. *When the secretion in the finer* [illegible]

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Pathologic Physiology. The patent ductus arteriosus forms an aorticopulmonary shunt, through which part of the arterial blood ejected from the left ventricle into the aorta is returned to the lungs. In this way the work of the left side of the heart is increased and in the course of time the left ventricle will hypertrophy and dilate. Should the ductus be of considerable size, the pressure in the pulmonary circulation will be increased and the work of the right ventricle will also be increased. In the case of a large ductus, therefore, both ventricles will hypertrophy. In an exceptionally large ductus, heart failure may develop in the first year of life.

Diagnosis. In 80 to 90 per cent of cases, the typical loud, harsh "*machinery murmur*" of the patent ductus will be a sufficient diagnostic criterion. The murmur is loudest in the second left intercostal space near the sternal border where a thrill often can be felt. In infants and adults the murmur will occasionally be atypical and heard only during systole. In case of doubt, cardiac catheterization is decisive. If the oxygen saturation in the pulmonary artery is at least one volume per cent higher than the highest value recorded in the right ventricle, the diagnosis is almost certain, although the rare possibility of an aorticopulmonary window should be kept in mind.

Prognosis and Complications. Without operation the average duration of life is about 30 years(12). At least half of the patients not operated upon will develop bacterial endocarditis; the majority of the other half will die of congestive heart failure.

Indications for Operation. All patients with a patent ductus arteriosus should be operated upon, even if they have no symptoms. However, operation should be postponed until the child is at least two years old, unless the ductus is of such size that it results in cardiac failure. Where a complicating bacterial endocarditis is refractory to prolonged antibiotic treatment, closure of the patent ductus may have a curative effect(41).

Operative Technic. A procedure for closure of the patent ductus arteriosus was described by Munro(28) in 1907, but not until 1938 was the first operation performed by Gross(23), who ligated the ductus with a single No. 8 braided silk ligature. As recanalization sometimes is seen after such simple ligation, it has now been abandoned. In most cases the following technic, slightly modified from Blalock(4), is suitable. The patient is placed in the supine position with the left side of the chest and the left shoulder slightly elevated by a folded sheet or drape. The left arm is abducted from the trunk. An anterolateral incision following the inframammary sulcus and curving up toward the posterior axillary line is used. The breast is dissected free and raised from the pectoral fascia. The pectoral muscles are divided over the fourth rib The anterior serratus digitation from the fourth rib is split in the direction of its fibers back to the long thoracic nerve. The intercostal muscles in the third interspace are then divided close to the cephalic border of the fourth rib in order to avoid cutting the intercostal vessels. The third and second costal cartilages are then exposed by elevating the overlying pectoral muscle with a retractor These cartilages are then divided obliquely from their outer surface near the sternum to their inner surface further laterally. Usually it is unnecessary to divide the internal mammary vessels which will lie beneath the sternal stumps of the divided cartilages. Cutting the cartilages obliquely gives a broader surface for subsequent

been loosened, the patient is asked to cough while the assistant exerts a steady pressure on the chest, especially over the site of the operative wound.

Should the patient be unable to bring up the secretions by coughing, they have to be removed by aspiration. Nasotracheal aspiration is carried out through a catheter, preferably with a slightly curved tip. A pillow is placed beneath the patient's shoulders so that the neck is extended and the tongue is held with a piece of gauze and pulled forward either by the patient himself or by an assistant. The catheter is introduced through one of the nostrils back to the nasopharynx, then during the beginning of an inspiration it is quickly passed through the glottis. A prompt coughing reflex, and movement of air through the catheter with respiration, will indicate that the catheter is in the trachea. Suction is then applied to the catheter intermittently while the catheter is moved up and down and rotated. If the secretions are thick and tenacious, a few milliliters of sterile salt solution injected into the trachea through the catheter will facilitate aspiration. This procedure is less traumatic than bronchoscopy and can be repeated as often as required. In small children, both bronchial aspiration and bronchoscopy are difficult to accomplish without specially trained personnel. Tracheotomy should therefore be performed without hesitation in such patients, and, if employed as a routine measure, can be done while the patient is still anesthetized after the operation is completed.

An oxygen tent is advisable after most operations, especially those for cyanotic heart disease, pulmonic stenosis, and constriction of the trachea by vascular rings. After the first 24 hours the patient is taken out of the tent intermittently and usually the use of the tent can be discontinued altogether after a few days. Postoperatively it is much more important to provide an atmosphere of high humidity than one of high oxygen content. This is particularly true with regard to children.

In uncomplicated cases, an antibiotic is given for four to six days after the operation. Due to the widespread use of penicillin many bacteria have become resistant to it, and some other antibiotic may be required if infection develops. The drainage catheter can be removed when the postoperative serosanguineous effusion has ceased, usually by the second or third day. Roentgenograms the day after operation, as well as the day before the patient is discharged, are helpful in disclosing conditions not always evident on physical examination.

PATENT DUCTUS ARTERIOSUS

Anatomy. The patent ductus is a vascular connection between the aorta distal to the origin of the left subclavian artery and the pulmonary artery in the first portion of its left branch. The ductus passes from the pulmonary artery posteriorly and caudally to its junction with the aorta. Its direction is thus an oblique one, rather than a right angled communication between the two great vessels. Generally the patent ductus is cylindrical or slightly funnel-shaped with the widest part near the aorta. The lumen may vary from bare patency to a lumen as great as that of the left pulmonary artery or aorta.

approximation and repair. A light rib spreader is then placed and the upper lobe of the lung is displaced downward and medially by a moist sponge and a malleable retractor. The mediastinal pleura is incised behind and parallel to the phrenic nerve. The patent ductus can now be located by the thrill felt through the covering loose aerolar tissue. The alveolar tissue is divided by sharp and blunt dissection to expose the aortic arch and pul-

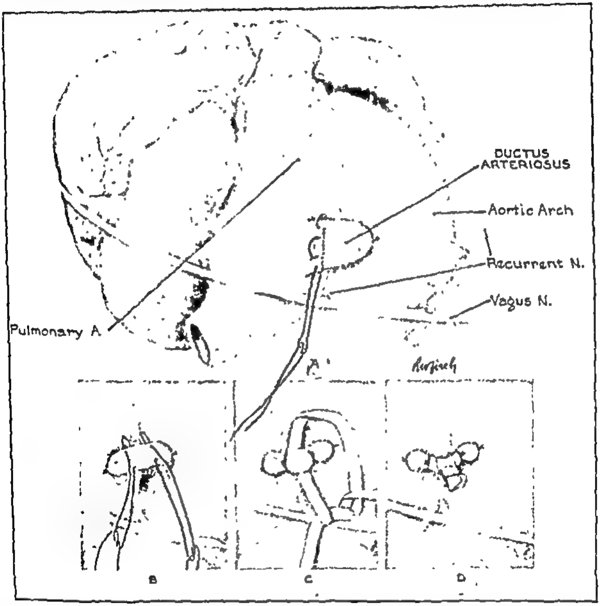

Fig. 3-2 Multiple ligation technic and umbilical tape ligature for closing patent ductus as described by Blalock However, a ligation technic, as described in the text, is quite satisfactory. Encircling ligatures are tied at both ends of the ductus and a transfixion ligature is placed between them. The size of the nonabsorbable suture material used should vary with the size of the ductus (From Blalock, A Surg, Gynec & Obst, 82 133, 1946)

monary artery. Beginning over the terminal part of the aortic arch, the dissection is carried up over the ductus, where several small lymph nodes have to be displaced or removed. Three or four traction sutures on the upper margins of the divided mediastinal pleura facilitate the exposure during this part of the dissection The pericardial reflection over the central part of the pulmonary artery extending up laterally to the ductus is freed and pushed back (Fig. 3-1). Thus both the great vessels are extensively freed

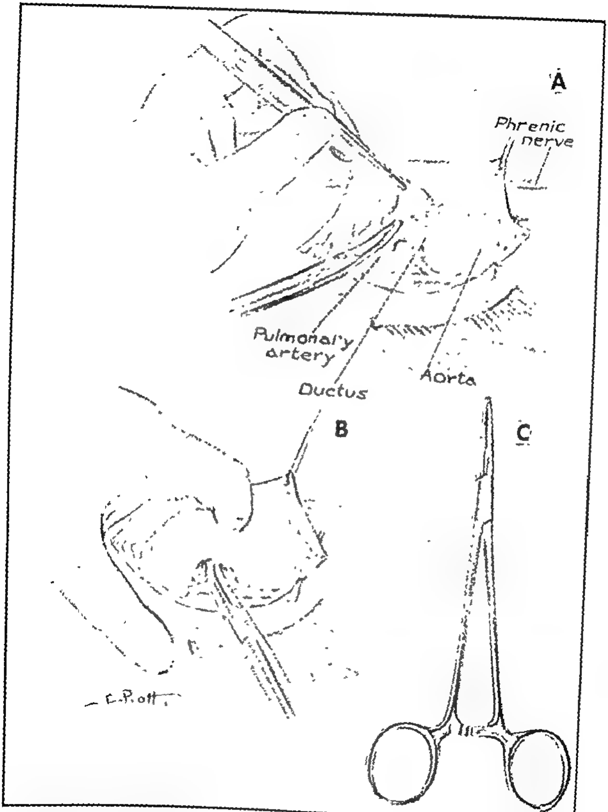

Fig 3-1 A, the clearing of the anterior surface of a patent ductus This dissection should be carried far medially B, blunt dissection posteriorly and medially, which must be carried out well medial to the ductus in order not to tear the posterior and medial wall of the ductus C, clamp with thin jaws used by Gross to clamp the ductus (From Gross, R E J Thoracic Surg, 16 314, 1947.)

of mediastinal tissue before the isolation of the ductus has begun. The vagus nerve is carefully isolated above and below the aortic arch and the recurrent laryngeal nerve identified and protected from injury. We prefer not to use ligatures around the vagus nerve for traction either above or below the aortic arch for fear of inadvertent injury to the recurrent nerve. The isolation of the ductus is then begun from its anterior surface in the tissue plane between the loose connective tissue and the adventitia which allows the freest and safest dissection. When the anterolateral surface has been cleared to the aortic and pulmonary angles, the ductus is encircled by blunt dissection on its posteromedial aspect. This part of the dissection should be carried out with great care in order not to tear the ductus inadvertently. Two No. 8 braided silk ligatures are then placed as near to each of the great vessels as possible and while gentle traction is made on each ligature in turn the other ligature is securely tied. Finally a transfixation suture is placed in the middle of the ductus to avoid recanalization if the two other ligatures should become loose (Fig. 3-2).

Though the operation generally will present no technical difficulties the dissection of the ductus can be troublesome if it is sclerotic and fragile or if inflammation around the ductus has made the connective tissue dense and difficult to separate from the ductus wall. Under such conditions the hazards of an inadvertent injury to the vessel will be far less if the aortic arch and pulmonary artery have been widely exposed, so that it will be possible to control bleeding and suture the vessels.

Complete Division of the Ductus. Complete divison of the ductus(21, 24) is probably advisable when the ductus is very large or funnel-shaped, when it is stiff and sclerotic, and when it is the seat of a bacterial endocarditis which has not responded to prolonged antibiotic treatment. The same anterolateral approach may be used as just described, but we prefer in these cases to use a posterolateral incision opening the thorax through the fourth interspace in children or resecting the fourth rib in adults. The additional exposure thus obtained facilitates isolation of the aorta and pulmonary artery above and below the ductus so that inadvertent hemorrhage from these vessels may be more easily controlled. After the ductus has been isolated, two Potts' clamps are placed on the ductus near its two ends. Each jaw of the clamp has numerous fine teeth which interdigitate slightly in the closed position, preventing it from slipping without crushing the vessel wall. The ductus is divided between the clamps and the edges are oversewn with continuous No. 5-0 Deknatel silk carried on an atraumatic needle (Fig. 3-3). The suture is then brought back and tied to the original end. Finally, two mattress sutures are placed behind each clamp before they are removed, to aid in exposure of the sutured stumps of the ductus if there should be any leakage of blood from the suture line.

COARCTATION OF THE AORTA

Anatomy. Coarctation of the aorta is a localized narrowing of the aorta in the vicinity of the ductus arteriosus. The stenosis is usually classified as being infantile or adult in type, though there is no distinct anatomic difference between the types. The infantile form is located between the left sub-

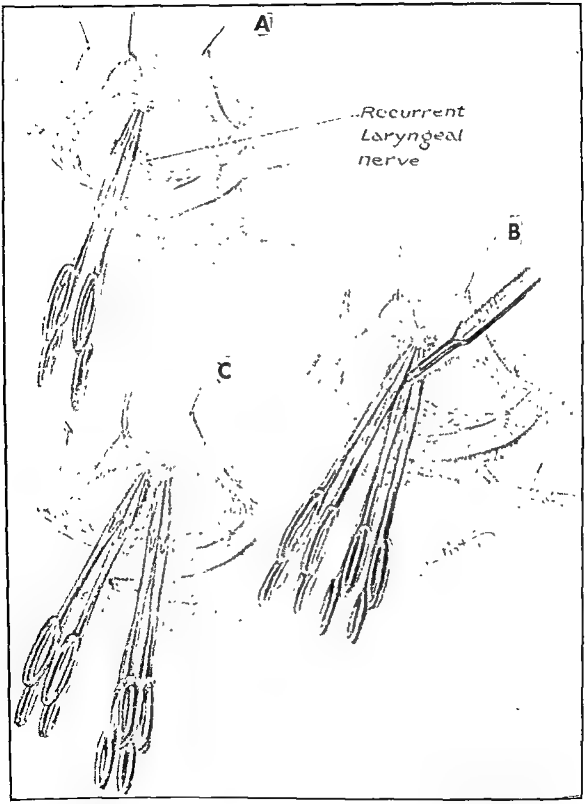

Fig 3-3. Division of the patent ductus as originally described by Gross A single Potts' clamp may be used on either end of the ductus instead of the double clamps shown The divided ends of the ductus may be closed with a continuous suture of No 5-0 Deknatel silk which is returned in a second row to its starting point or by a series of interlocking mattress sutures of the same material. Intima should be approximated to intima (From Gross, R. E J Thoracic Surg., 16:314, 1947.)

of mediastinal tissue before the isolation of the ductus has begun. The vagus nerve is carefully isolated above and below the aortic arch and the recurrent laryngeal nerve identified and protected from injury. We prefer not to use ligatures around the vagus nerve for traction either above or below the aortic arch for fear of inadvertent injury to the recurrent nerve. The isolation of the ductus is then begun from its anterior surface in the tissue plane between the loose connective tissue and the adventitia which allows the freest and safest dissection. When the anterolateral surface has been cleared to the aortic and pulmonary angles, the ductus is encircled by blunt dissection on its posteromedial aspect. This part of the dissection should be carried out with great care in order not to tear the ductus inadvertently. Two No 8 braided silk ligatures are then placed as near to each of the great vessels as possible and while gentle traction is made on each ligature in turn the other ligature is securely tied. Finally a transfixation suture is placed in the middle of the ductus to avoid recanalization if the two other ligatures should become loose (Fig. 3-2).

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clavian artery and the ductus, which often is patent. It is frequently associated with other severe cardiac malformations which may cause death at an early age. The adult form, found in most patients past two or three years old, is a relatively short stenosis immediately distal to the ligamentum arteriosum. Central to the stenosis the aorta may be hypoplastic or dilated and in most cases the left subclavian artery is dilated(13).

During the first years of life, a considerable collateral circulation is developed which permits blood from the branches of the subclavian and carotid arteries to reach the aorta distal to the stenosis. The majority of the anastomoses originate from the subclavian artery and its branches. The first two intercostal arteries from the subclavian artery and its branches to the neck and scapula form a network of anastomoses with the intercostal arteries from the aorta. The internal mammary artery forms anastomoses with the intercostal, musculophrenic and mediastinal branches from the aorta. Spinal branches from the vertebral arteries form anastomoses via the spinal arteries with the intercostal arteries from the aorta. The dilated and twisted anastomoses can be palpated or even be seen pulsating over the scapula and in the intercostal spaces. Atherosclerotic changes frequently occur in the aorta as early as the third decade of life. Large thin walled aneurysmal dilatations occur early in the intercostal arteries at their origin from the aorta.

Pathologic Physiology. The coarctation results in increased work for the left ventricle, partly because the resistance to blood flow through the stenosis and the collateral vessels exceeds the resistance in a normal aorta, and partly because in the course of time renal hypertension develops because of decreased circulation through the kidneys.

Diagnosis. The subjective complaints in coarctation can be divided into three groups: cardiac symptoms, cerebral symptoms such as headache and dizziness, and symptoms referable to the lower extremities such as a sense of heaviness or fatigue in the legs on exertion. The diagnosis can be established by finding an increased blood pressure in the brachial arteries and an abnormally low pressure in the femoral arteries together with the palpable or visible collateral circulation over the upper thorax posteriorly. Hypertrophy of the left ventricle and notching of the ribs will appear on roentgenograms of the chest. Cardiac catheterization will be of no assistance in the diagnosis and is not indicated unless there is suspicion of a complicating malformation. Angiocardiography often gives a good picture of the malformation and the collateral circulation but little information about operability.

Prognosis and Complications. In many cases symptoms do not occur until adolescence or adult age. Not infrequently patients have completed a tour of duty in the military service or have undergone a normal pregnancy and delivery. Later on, however, the characteristic symptoms will appear and the average duration of life is not more than 35 years(34). In Abbott's series(2), 75 per cent died before the age of 40. The main causes of death were cerebral hemorrhage and intrathoracic hemorrhage, from rupture of the aorta or intercostal arteries in the 20 to 30 year age group. Bacterial endocarditis with sepsis and heart failure were the leading causes of death in the 30 to 50 year age group.

Indications for Operation. Considering the unfavorable prognosis after the age of 25 years, operation should be performed at an earlier age, even when the patient has no complaints. The best results can be expected from operations performed between the ages of 10 and 15 years. At this age the operative mortality is comparatively low and the diameter of the aorta permits an anastomosis of satisfactory size This is an important consideration, as the extent to which the lumen of the anastomosis will enlarge with growth of the aorta is still unknown After 30 years of age the operative mortality increases considerably because of atherosclerotic changes in the aorta.

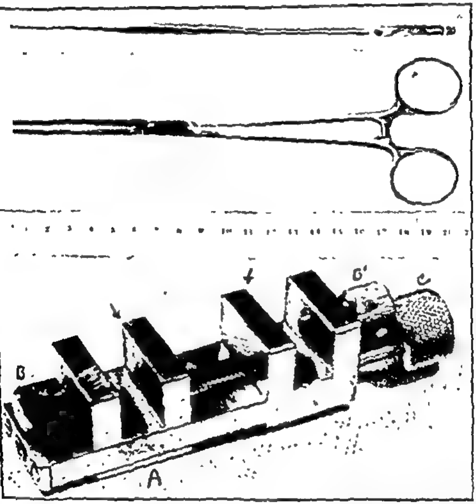


Fig 3-4 At the top are two views of Potts' multitoothed clamp. The teeth keep the wall of the blood vessel from slipping, yet the clamp does not crush the vessel At the bottom is shown the vise for holding the clamps in apposition when anastomosing the aorta (From Potts, W. J Ann Surg., 131.466,1950.)

Operative Technic. Resection of a coarctation of the aorta was first performed in man by Crafoord in 1945(13, 22, 31). The patient is placed in the left lateral recumbent position with the left arm drawn forward and up and the forearm flexed. A posterolateral incision with resection of the fifth rib is used. If greater exposure proves desirable in adults, small portions of the fourth and sixth ribs may be resected posteriorly Because of the extensive collateral circulation this part of the operation may prove quite time consuming. The parietal pleura over the stenosed part of the aorta is cut longitudinally. The aorta above and below the stenosis, and also the sub-

clavian artery, the ligamentum arteriosum and the upper intercostal arteries, must be completely exposed and mobilized. This is a painstaking part of the operation as the intercostal arteries are dilated and thin walled and may rupture at the slightest touch. The ligamentum arteriosum, or in some cases the patent ductus, is doubly ligated and divided. Two pairs of inter-

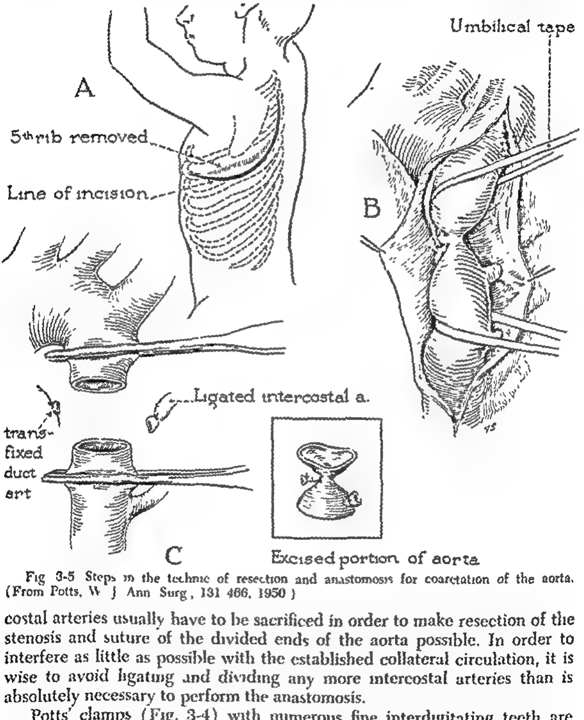


Fig 3-5 Steps in the technic of resection and anastomosis for coarctation of the aorta. (From Potts, W J Ann Surg, 131 466, 1950)

costal arteries usually have to be sacrificed in order to make resection of the stenosis and suture of the divided ends of the aorta possible. In order to interfere as little as possible with the established collateral circulation, it is wise to avoid ligating and dividing any more intercostal arteries than is absolutely necessary to perform the anastomosis.

Potts' clamps (Fig. 3-4) with numerous fine interdigitating teeth are placed above and below the stenosed part of the aorta, preferably 2 cm. from the proposed lines of resection The stenosed segment is then excised, dividing the aorta above and below the stenosis in such a way as to provide aortic lumens of equal circumference for the anastomosis. The divided ends of the aorta are then brought together by an assistant holding the clamps

Alternately Potts' adjustable vise may be used (Fig 3-5). This vise holds both clamps in the desired coaptation during suturing.

Different methods of suturing are currently employed. Crafoord and others prefer a continuous running suture, interrupted at intervals, producing end-to-end coaptation of the aortic wall. The advantage of this method is that it allows resection of a few more millimeters of the obstruction. Probably a stronger and safer anastomosis is obtained with an everting intima-to-

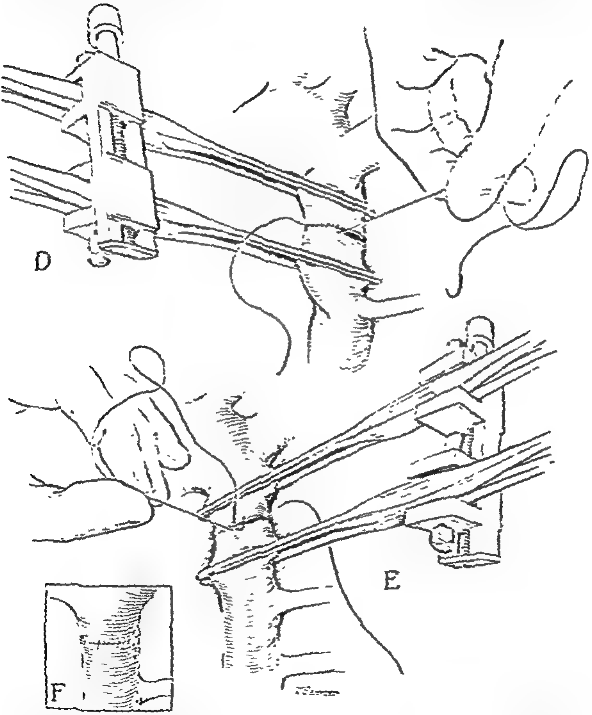
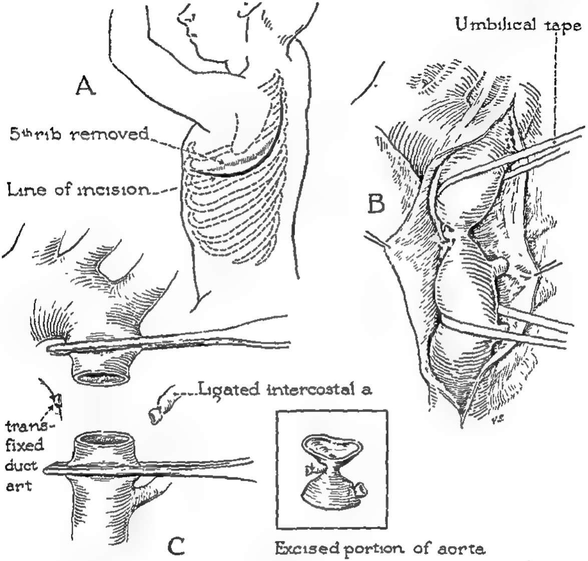


Fig. 3-5 cont. D, the clamps held by the vise are turned upward while the posterior suture line is placed. E, the clamps are returned to their original position for completion of the anterior suture line of the anastomosis. (From Potts, W. J.: Ann. Surg., 131:466, 1950.)

intima mattress suture. If a continuous mattress suture is placed in the posterior one third of the circumference, it will facilitate the most difficult part of the suturing. Interrupted sutures placed at equidistant intervals of approximately one millimeter are used for the rest of the anastomosis. It is

clavian artery, the ligamentum arteriosum and the upper intercostal arteries, must be completely exposed and mobilized. This is a painstaking part of the operation as the intercostal arteries are dilated and thin walled and may rupture at the slightest touch. The ligamentum arteriosum, or in some cases the patent ductus, is doubly ligated and divided. Two pairs of inter-



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Alternately Potts' adjustable vise may be used (Fig. 3-5). This vise holds both clamps in the desired coaptation during suturing.

In some cases the anterior arch will be obliterated but frequently it has a considerable lumen. The vessels which normally originate from the aortic arch can arise from either the posterior arch alone or from both arches. The aorta usually descends on the left, but may be on the right side. Not infrequently, a double aortic arch is combined with a patent ductus arteriosus.

Pathologic Physiology. If the vascular ring is large enough it will cause no symptoms. At postmortem examination of aged persons, a double aortic arch has been seen as an incidental finding. However, if the vascular ring is narrow, it will compress the trachea and esophagus resulting in respiratory distress, stridor, coughing, repeated episodes of respiratory tract infection and dysphagia.

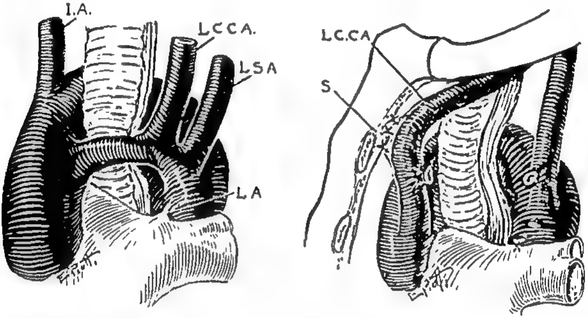


Fig 3-6. Common form of double aortic arch with anterior arch smaller than the posterior arch The anterior arch was divided between the left common carotid and left subclavian arteries. The former vessel is sutured to the sternum to elevate it from the trachea. In the type of double arch shown here, division of the anterior arch between its origin from the ascending arch and the left common carotid artery, will also relieve the tracheal compression The site chosen for the division of the arch should be such as to leave an adequate cuff distal to the ligatures after division. (From Gross, R E Surgical Treatment for Abnormalities of the Heart and Great Vessels, 1947. Courtesy Charles C Thomas Publisher)

Diagnosis. A double aortic arch should be suspected in infants and small children who have exhibited the above symptoms from birth(42). The symptoms are especially pronounced when the child is eating and may disappear completely during sleep. A posteroanterior roentgenogram will confirm the suspicion of a vascular ring if the mediastinal shadow is widened, especially to the right, and the aortic knob is not seen on the left side. Lateral roentgenograms with contrast media in the esophagus will demonstrate forward displacement and a defect in the posterior contour of the esophagus. Visualization of the trachea after instillation of Lipiodol is not necessary and is inadvisable in children with a partially occluded airway. It is important to determine on which side the aorta descends for this is the side on which the

important that every stitch be tied with exactly the proper tension to coapt the edges snugly. If tied too loosely bleeding will occur; if tension is excessive the suture will tend to cut through the wall of the vessel. When the anastomosis has been finished, the distal clamp is released first. Some oozing from the suture line always occurs but soon ceases. If there is a leak in the suture line, additional stitches must be placed. The proximal clamp is then released very slowly while the blood pressure is closely observed. Finally both clamps are removed.

In some cases the anastomosis cannot be performed as described above. The stenosis may be situated very close to the subclavian artery or it may be of a length which makes end-to-end anastomosis impossible. If the proximal part of the aorta is continued in a U bend into the hypertrophic subclavian artery and the stenosed part of the aorta comes off from the base of the curve, it is necessary to clamp the subclavian artery as well as the aorta between the left common carotid and left subclavian arteries. When the stenosed portion is excised an opening is left at the lowest point of the aortic subclavian curve. The anastomosis then performed will really be end-to-side. If the stenosed segment of the aorta is so long that it is impossible to anastomose the ends directly after the resection, the subclavian artery can be divided as far distally as possible and swung down and anastomosed to the distal portion of the aorta. This method has two serious disadvantages Approximately half of the collateral circulation will be destroyed when the subclavian artery is cut, and it is difficult to swing the subclavian artery down without partially obstructing its lumen by folding at its base. It is preferable, under these circumstances when the ends of the aorta cannot be anastomosed directly, to use an aortic homograft. Such grafts are being increasingly widely used, and are now available in most medical centers where there is an interest in vascular surgery. They are preferably obtained from young individuals dying of hemorrhage or accident. They may, however, be obtained from the body of any individual not dying with infection and in whom there is no gross evidence of arteriosclerosis, cancer, or other general systemic disease. The freeze-dry method of preserving these grafts is probably the best method in use at the present time (29). The grafts are reconstituted in saline, all branches are securely ligated and the graft, cut to the proper length, is sutured in place to bridge the gap between the ends of the aorta in the manner described above.

DOUBLE AORTIC ARCH

Anatomy. The aortic arch is normally developed from the fourth left branchial arch. The proximal portion of the corresponding primitive right arch forms the origin of the right subclavian artery, while the distal part disappears. If this development is disturbed, at approximately the sixth week of fetal life, a double aortic arch may be formed. One of them, and in most cases the larger, passes behind the esophagus and the trachea, while the smaller anterior arch originating from the ascending aorta at the base of the heart crosses in front of the esophagus and trachea to join the posterior arch and form the descending aorta (Fig. 3-6).

considerable variation from the normal relationship. None of these variations are significant unless they produce compression of the trachea or esophagus. When they cause such compression operation should be performed to relieve the compression. The operation may consist of displacing the offending vessel into such a position where it will not compress the trachea or esophagus, or the vessel may be ligated and divided. It is not advisable to ligate and divide the innominate or the common carotid artery because of the danger of cerebral complications. When the subclavian artery is causing the compression it may be divided with impunity as there is always an adequate collateral circulation to the upper extremity.

Gross has reported compression of the trachea by the innominate and left common carotid arteries. The compression was relieved by suturing the adventitia of the vessel at fault to the sternum thus elevating the vessel from the trachea and relieving the compression.

The commonest anomaly of the subclavian vessels is a right subclavian artery originating from the most distal portion of the aortic arch beyond the left subclavian. From this origin the vessel passes upward and to the right to reach the apex of the right thorax. In the vast majority of cases, the artery passes behind the esophagus, producing an oblique indentation on the posterior aspect of the esophagus. This may produce no symptoms but it may result in difficulty with swallowing which is referred to as dysphagia lusoria. The condition may be simply and effectively corrected by ligation and division of the subclavian artery at its point of origin (Fig. 3-7).

PULMONARY STENOSIS

Anatomy. The collective term pulmonary stenosis includes constrictions either of the pulmonary valves or of the infundibulum of the right ventricle or both. Numberless variations and combinations of valvular and infundibular stenosis occur. The usual valvular stenosis consists of a conical diaphragm with a narrow hole formed by the fused pulmonic valves. The pulmonary artery is narrowest near the ostium, then widens in the usual poststenotic dilatation. The infundibulum may have developed as an elongated, narrow, funnel-shaped tube (Fig. 3-8A). Frequently the infundibulum is continued into a stenotic ostium with a bifid valve. The pulmonary artery, too, may be hypoplastic; in some cases there is atresia of one of the main branches. There may be a localized infundibular stenosis consisting of a narrow fibrous or muscular ring. The constriction may be at the beginning of the infundibulum, thus dividing the right ventricle into an inflow tract and a poststenotic dilated outflow tract (Fig. 3-8D, F), or it can be situated very near the ostium of the pulmonary artery (Fig. 3-8B).

These different types of pulmonary stenosis may occur alone or they may be associated with other developmental anomalies. The commonest associated anomalies are interatrial septal defects and interventricular septal defects with dextrarotation of the aorta. The former is commonly referred to as Morgagni's syndrome and the latter as the tetralogy of Fallot. These three groups, isolated pulmonary stenosis, Morgagni's syndrome, and the tetralogy of Fallot, will be considered separately.

surgical approach is made. Angiocardiography may be done to establish the course of the descending aorta.

Prognosis and Indications for Operation. When symptoms have been present since infancy the prognosis without operation is very grave(42). If there is constant respiratory distress and feeding is difficult, one should operate regardless of age. With less pronounced symptoms, it is reasonable to wait until the age of two years.

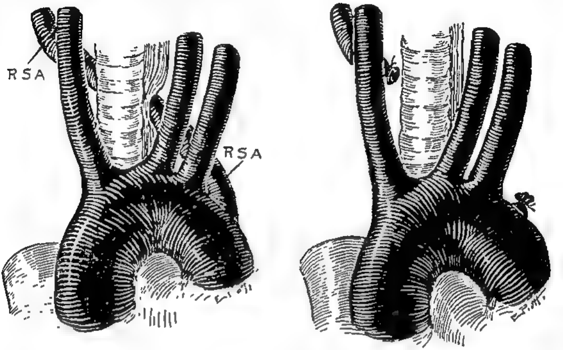


Fig 3-7. The common type of anomalous origin of the right subclavian artery producing compression of the esophagus. Simple division of the artery relieves the compression (From Gross, R. E. Surgical Treatment for Abnormalities of the Heart and Great Vessels, 1947. Courtesy Charles C Thomas Publisher)

Operative Technic. In 1945, Gross(20) reported the first operation for a double aortic arch in a one year old child. Since then the operation has been successfully employed in numerous cases(25, 38). With the patient in the lateral position, the thorax is opened through a posterolateral incision in the fourth intercostal space on the side of the descending aorta where the anterior arch is to be found. The mediastinal pleura is incised and the anterior aortic arch is dissected free, until its branches are in view. The recurrent laryngeal branch of the vagus nerve is carefully preserved. If a patent ductus is found it is ligated. The most suitable site for division of the anterior arch is where there is sufficient room between the branches to provide an adequate cuff of aorta distal to the ligatures after division. Double ligatures of No. 6 braided silk are placed around the arch and the arch is divided. As soon as the vascular ring is cut, it will immediately retract and the compressed esophagus and trachea rise forward (Fig. 3-6). Closed drainage of the pleural cavity is established through a separate stab wound.

Anomalous Branches of the Aortic Arch. The positions and points of origin of the innominate, carotid, and the subclavian arteries may show

tion but the diagnosis should already be established by the catheterization. Some authors(16) warn against angiocardiography when a pronounced stenosis is anticipated and there is no interventricular septal defect.

Prognosis and Complications. In a survey of the published cases of isolated pulmonary stenosis, Greene et al.(19) found the average duration of life to be 26 years. More than half of the patients reached adult age and a few of them lived to their seventies. Cardiac failure was the most frequent cause of death. The next frequent were bacterial endocarditis and pulmonary tuberculosis.

Operative Indications. The operation of choice in isolated pulmonary stenosis is valvotomy. Whether patients without symptoms, or with slight symptoms, should be operated upon is not yet agreed on. The mortality rate for pulmonary valvotomy has until recently been comparatively high, being 15 per cent in the most skillful hands. However, these results will undoubtedly improve with increasing experience and with the performance of more operations at an earlier stage before congestive heart failure has developed. In view of the rather short interval between the appearance of severe symptoms and the final deterioration of the patient, it seems wise to perform valvotomy in cases where the systolic pressure in the right ventricle approaches or exceeds the systolic peripheral blood pressure, even though the patient still has considerable physical capacity.

Valvotomy for Pulmonary Valvular Stenosis. Doyen(15) in 1913 attempted operative correction of pulmonic stenosis. The patient, who had a tetralogy of Fallot with a subvalvular stenosis, did not survive. In 1948, Sellors(35) performed the first successful pulmonary valvotomy. Owing to Brock's elaboration of the surgical technic(9, 10), this operation now has passed the experimental phase and can be counted as a well established intracardiac procedure.

TECHNIC. A posterolateral incision in the fourth interspace or through the bed of the fourth or fifth rib may be employed. However, an anterolateral incision in the fourth or fifth interspace with division of the costal cartilages of two or three cephalad ribs gives a quite adequate exposure. We prefer an anterolateral incision because it facilitates pulmonary ventilation during the operation, requires less time to open and close, results in less postoperative discomfort, and provides adequate exposure. The cartilages should be divided close to the sternum to provide as much exposure of the anterior surface of the heart as possible. The internal mammary vessels should be ligated and divided. As soon as the pleura is opened, 5 ml. of 2 per cent procaine is injected into the pericardium and an intravenous drip of 0.1 per cent procaine solution is started to diminish cardiac irritability and the likelihood of ectopic rhythm during subsequent manipulations. The lung is retracted posteriorly with a moist pack. At intervals during the course of the operation, this pack should be removed and the lung completely re-expanded. Failure to observe this precaution may result in the necessity of employing excessive positive pressure to reinflate the lung at the conclusion of the operation. The pericardium is opened with a longitudinal incision anterior and parallel to the phrenic nerve. The upper flap of pericardium is bisected by an incision at right angles to the first incision. The corners thus created are sutured temporarily to the structures of the

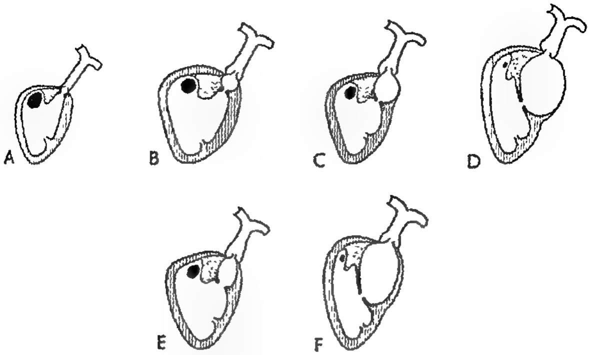


Fig. 3-8 Diagrams of common forms of infundibular stenosis. (From Brock, R. C., and Campbell, M. Brit. Heart J., 12.403, 1950.)

ISOLATED PULMONARY STENOSIS

Anatomy. Isolated pulmonary stenosis as the sole anomaly is, in the majority of cases, valvular. Infundibular stenosis, however, was observed in 25 per cent of 68 cases reported by Greene et al.(19) in 1949.

Pathologic Physiology. Functionally the pulmonary stenosis produces an isolated stress on the right ventricle. As the ventricle possesses a considerable functional reserve, the patient often will remain well compensated for many years. When compensation is overcome, congestive heart failure occurs. It has been shown by means of cardiac catheterization(9, 18) that the pulmonary artery pressure in the right ventricle is considerably increased and may even exceed the systolic peripheral blood pressure. The pressure in the right ventricle thus gives a better indication of the degree of stenosis than does the pulmonary artery pressure.

Diagnosis. The complaints are often few and slight. Dyspnea on exertion and palpitation may be the only symptoms. On auscultation a harsh, systolic murmur, heard best in the first to the third left intercostal space near the sternal border, is a constant finding. Often a thrill can be felt here. Roentgenograms show a heart of normal size or with an enlarged right ventricle. A poststenotic dilatation of the pulmonary artery can be seen in most cases while the vascular markings of the peripheral lung fields as a rule are normal. Cardiac catheterization will confirm the diagnosis. The stenosis manifests itself by an increased systolic pressure in the right ventricle and an abnormal fall in pressure from the ventricle to the pulmonary artery. The presence of the catheter passing through the stenotic area into the pulmonary artery will further increase the obstruction at this point and thus further exaggerate [illegible] between the right ventricle and pulmonary artery. [illegible] the poststenotic dilata-

to the turbulence produced by the narrow jet of blood from the valve orifice entering the enlarged artery. The firm cone formed by the fused pulmonic valve cusps may also be palpated by momentarily invaginating the wall of the pulmonary artery.

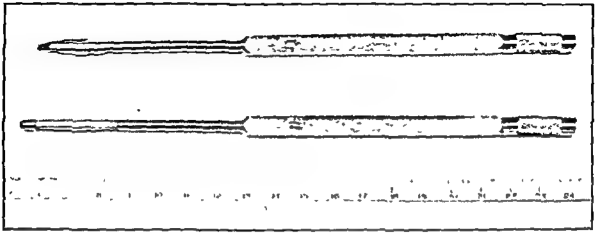
Brock's valvulotomes may be used to cut the stenotic pulmonary valve. We prefer, however, the Potts' valvulotome and dilator (Fig. 3-9) as the cutting and dilating components of both these instruments can be retracted into the shaft so that the instrument can be passed through the wall of the right ventricle by way of a very small stab wound. Therefore, after confirming the diagnosis, Potts' valvulotome is opened to a width a few millimeters less than the estimated internal diameter of the pulmonary artery. This estimation is aided by holding the cutting portion of the instrument adjacent to the pulmonary artery while the instrument is opened to the estimated proper width. The indicator on the instrument is then read and the blades are again closed.

Two everting mattress sutures of silk on atraumatic needles are then placed in the right ventricle, one on each side of the intended stab wound, which should be located approximately halfway between the pulmonary valve and the apex. The area selected should be such as to avoid division of coronary vessels. With a bayonet type scalpel a stab wound is then made through the wall of the right ventricle. Slight traction on the mattress sutures easily controls bleeding after the wound is made. Potts' valvulotome, in the closed position is then inserted into the right ventricle and passed upward until it reaches the stenotic valve (Fig. 3-10). The blades are then opened to the predetermined width and the knife is pushed forward into the pulmonary artery dividing the fused valve. A sense of resistance suddenly overcome can be detected as the valve is cut. Accidental injury to the walls of the pulmonary artery is avoided by the surgeon's other hand which palpates the blunt tip of the knife through the wall of the artery and checks its advance The blades are then drawn back into the shaft of the instrument and the instrument withdrawn from the pulmonary artery and right ventricle. As the instrument is withdrawn, bleeding from the wound in the right ventricle is controlled by gentle traction on the stay sutures aided by placing the tip of the finger over the wound. Potts' dilator is then inserted in the closed position and passed up to the region of the pulmonary valve. It is then opened to the predetermined width. The dilating bands are then withdrawn into the shaft of the instrument which is then withdrawn from the pulmonary artery and the right ventricle.

The myocardial wound is closed by tying first one and then the other mattress silk sutures. Additional sutures are generally unnecessary. The pericardial edges are loosely approximated with a few interrupted sutures allowing free drainage from the pericardial sac into the left pleural cavity. As usual, a catheter for pleural drainage is left in place for 36 or 48 hours.

Dilatation and Infundibular Resection for Infundibular Stenosis. In infundibular stenosis, the operative procedure will depend upon the site of the stenosis In a subvalvular or high stenosis with a short and thin walled poststenotic chamber, the myocardial incision is placed below the stenosis. When the stenosis is low, at the beginning of the infundibulum, and the

chest wall. A series of traction sutures are placed along the margin of the posterior flap and a hemostat attached to every three or four of these sutures. These maneuvers stabilize the pericardium and heart during subsequent manipulations.



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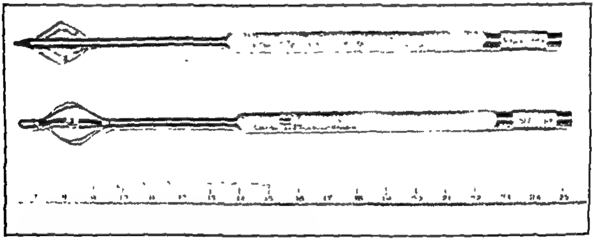

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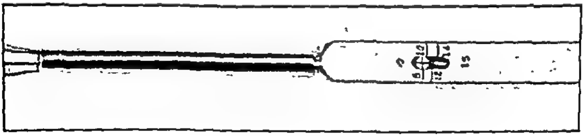

C

Fig. 3-9. The Potts' valvulotome and dilator for pulmonic valvular stenosis. The cutting and dilating blades are withdrawn into the shaft in A, and are opened in B. A close-up view of the handle, C, shows the device indicating the extent to which the blades have been opened (From Potts, W. J., and Riker, W. O. Arch. Surg., 62:776, 1951.)

To verify the diagnosis, the conus of the right ventricle and the pulmonary artery are inspected and palpated. A systolic thrill is always palpable in the dilated pulmonary artery beyond the stenosed pulmonary valve due

to the turbulence produced by the narrow jet of blood from the valve orifice entering the enlarged artery. The firm cone formed by the fused pulmonic valve cusps may also be palpated by momentarily invaginating the wall of the pulmonary artery.

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poststenotic chamber is of sufficient size with a muscular wall, the incision is made in the wall of the chamber and the stenosis is attacked in retrograde fashion.

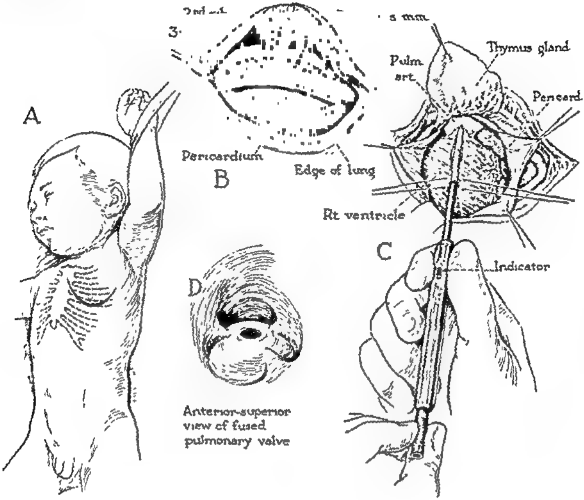

Fig. 3-10 Steps in the division and dilatation of a stenotic pulmonary valve using Potts' special instruments. (From Potts, W. J., and Riker, W. O. Arch. Surg., 62:778, 1951.)

After the incision has been made, the probe is inserted to confirm the presence and the level of the obstruction. Then a Brock's punch (Fig. 3-11) of suitable size (0.7, 1.0 or 1.25 cm. in diameter) is inserted, opened, and directed through the stenosis. When the blunt, projectile-shaped head has passed the stenosis, the fibrous ring snaps back into the narrow neck of the punch between the cutting edges. The punch is closed and drawn back; the resected tissue is held firm by the instrument. Sometimes the procedure has to be repeated. If necessary, this is done with a punch of a larger diameter. After the resection, dilators of increasing diameters are utilized; one is directed through the pulmonary valve to insure that there is no complicating valvular stenosis.

Though Brock's punch still remains the best instrument for resection of infundibular stenosis, the amount of tissue resected, particularly when the constriction is of some length, will be uncertain. According to Brock and Campbell(11), remarkable results can be obtained by simple dilatation without resection.

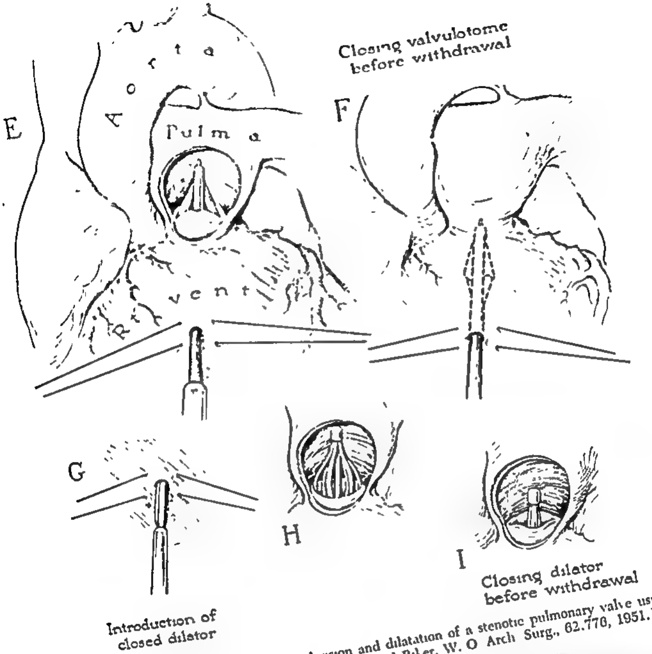

Fig. 3-10 (cont.). Steps in the division and dilatation of a stenotic pulmonary valve using Potts' special instruments (From Potts, W J, and Riker, W. O Arch Surg., 62.770, 1951.)

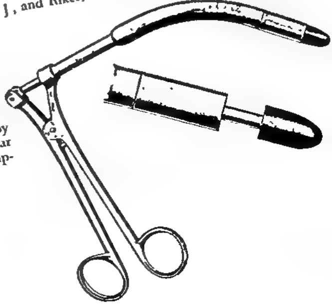

Fig 3-11. The punch devised by Brock for operative relief of infundibular stenosis. (From Brock, R. C, and Campbell, M. Brit. Heart J., 12.403, 1950)

PULMONARY STENOSIS WITH ATRIAL SEPTAL DEFECT (MORGAGNI'S SYNDROME)

Because of the difference in the surgical treatment, it is of great importance to distinguish between this by no means rare syndrome and the tetralogy of Fallot, to which it bears a great resemblance clinically(36). Patients with pulmonary stenosis and an atrial septal defect but without any interventricular communication will develop heart failure after creation of a Blalock anastomosis(16, 39), whereas a pulmonary valvotomy will be of benefit.

Pathologic Physiology. In Morgagni's syndrome, there is a right to left shunt through the atrial defect and a decreased pulmonary blood flow. The size of the venoarterial shunt depends upon the size of the atrial septal defect and to what degree the pulmonary stenosis increases the pressure in the right atrium. While these patients as a rule are cyanotic, the shunt can in some cases be potential with cyanosis appearing only after physical exercise. In others, the shunt appears when the right atrial pressure rises subsequent to right ventricular failure.

Diagnosis. Clinically the Morgagni syndrome resembles the milder cases of Fallot's tetralogy (see below). The auscultatory and roentgenologic findings are very similar to those found in isolated pulmonary stenosis. Cardiac catheterization will establish the diagnosis. The following findings are necessary: 1, decreased arterial oxygen saturation during exercise and possibly at rest; 2, evidence of an intact interventricular septum shown by a significant difference between the systolic pressure in the right ventricle and the peripheral arteries and no increase in the oxygen content of the blood in the right ventricle; and 3, an increased systolic pressure in the right ventricle and a significant pressure fall from the ventricle to the pulmonary artery

Indications for Operation. Even in mild cases, the prognosis is less favorable than for isolated pulmonary stenosis(36). Therefore, as soon as the diagnosis is established, pulmonary valvotomy should be performed. The technic is similar to that described above.

THE TETRALOGY OF FALLOT

The tetralogy of Fallot is by far the most frequent type of cyanotic congenital heart disease. Probably the best description of this malformation may be given in Fallot's own words, "This malformation consists of a true anatomicopathologic type represented by the following tetralogy: 1, stenosis of the pulmonary artery, 2, intraventricular communication; 3, deviation of the origin of the aorta to the right, and 4, hypertrophy, almost always concentric, of the right ventricle. Failure of obliteration of the foramen ovale may occasionally be added in a wholly accessory manner." The pulmonary stenosis in the tetralogy of Fallot is of the valvular type in 40 to 50 per cent of the cases; the remaining cases are of the infundibular or combined type(9, 12, 26).

Pathologic Physiology. The anatomic malformations in Fallot's tetralogy result in a decreased flow through the pulmonary artery to the lungs and a

shunting of blood from the right ventricle directly into the aorta. The size of the venoarterial shunt will depend on the degree of dextroposition of the aorta, the degree of pulmonary stenosis, and, to some extent, upon the size of the septal defect. Due to the ventricular septal defect, the systolic blood pressure in the right ventricle will not be able to rise above the pressure in the left ventricle as it may in pulmonary stenosis with an intact ventricular septum. The flow of blood through the pulmonary artery will, therefore, be less in the tetralogy than in an isolated stenosis, given the same degree of stenosis.

Patients with Fallot's tetralogy reaching adult age develop an extensive collateral circulation between the pulmonary arteries and the dilated bronchial arteries and other vessels from the aorta to the lungs. This collateral circulation may develop to such an extent that some patients will experience an increased exercise tolerance for a number of years.

Diagnosis. The predominant symptoms are cyanosis from an early age, dyspnea on exertion, squatting, clubbing of fingers and toes, and physical underdevelopment. It is of differential diagnostic interest, especially with regard to Eisenmenger's syndrome (i.e., ventricular septal defect, overriding of the aorta, but no stenosis of the pulmonary artery), that hemoptysis does not occur in Fallot's tetralogy(18).

The roentgenogram reveals a normal or slightly enlarged heart with the apex turned upward as a result of rotation due to enlargement of the right ventricle. The left border of the heart is concave because of hypoplasia of the pulmonary artery and of the conus of the right ventricle. These two facts result in the characteristic boot-shaped appearance of the heart in the posteroanterior roentgenogram. The hilar shadows are small and the lung fields are abnormally clear.

Even when the clinical and roentgenologic picture is sufficient to establish the diagnosis, cardiac catheterization should be done, as it will give information which is helpful in deciding the type of operation to be performed. The findings of cardiac catheterization can be summarized as follows. There is a considerable fall in pressure from the right ventricle to the pulmonary artery. The catheter may pass through the defect into the left ventricle and aorta. Finally, the systemic arterial blood will not be normally saturated with oxygen.

Special attention should be paid to the catheterization of the pulmonary artery, as it affords information on the nature of the stenosis. By simultaneous observations of the pressure curves and of the position of the tip of the catheter as it is drawn back from the pulmonary artery into the right ventricle, it is possible to determine where the shape of the curve changes and thus get an idea of the nature of the stenosis (i.e., valvular or type of infundibular).

Prognosis and Complications. In Abbott's series(1) of 97 cases of tetralogy of Fallot, the average duration of life was nine years. The oldest patient was 28 years of age. However, occasionally cases are reported of patients living to the fourth or fifth decade. Patients with atresia of the pulmonary artery have the shortest life expectancy, succumbing usually in the first year during an attack of severe cyanosis. The most frequent causes of death in those patients living past one year are pneumonia, cerebral thrombosis as a

result of the pronounced polycythemia, and for those with a longer span of life, bacterial endocarditis and congestive heart failure.

Indications for Operation. The grave prognosis without operation, as compared with the favorable results of operation, leaves no doubt that patients with the tetralogy of Fallot should be operated upon. The choice of operation lies between the creation of a fistula between a systemic and a pulmonic artery, the Blalock-Taussig or the Potts' operation, and a pulmonary valvotomy or pulmonary infundibular resection. The objective in both types of operations is to increase the pulmonary blood flow(17).

The results of pulmonary valvotomy(9, 10) in recent years make it appear to be the operation of choice in pulmonary valvular stenosis, which is found in approximately one half of the cases of tetralogy of Fallot. Also from an anatomic and physiologic point of view, it seems more reasonable to increase the pulmonary blood flow by correcting one of the existing defects instead of creating a new one, as in the anastomotic operation. The operation of choice in patients with infundibular stenosis is not as clear(11, 14, 35). Infundibular resection still has a high mortality rate in the hands of most surgeons and the long-term functional results have not yet been determined. When one encounters pulmonary atresia (found in one fourth of Abbott's 97 cases of tetralogy of Fallot), an anastomotic operation is the only choice. In conclusion, a pulmonary valvotomy is indicated in patients with a valvular stenosis and, until the technic and results of infundibular resection have improved, one should probably do an anastomotic operation in infundibular stenosis.

Of the anastomotic operations, the Blalock-Taussig operation is to be preferred, if there is a subclavian artery suitable for the operation. In the Potts' operation, it may be difficult to create an anastomosis of exactly the proper size, and there is no way of controlling how much the arteriovenous fistula will increase in the course of time. Considering that the amount of blood shunted through the anastomosis increases with the square of the radius of the anastomosis, an anastomosis a few millimeters larger than desired will produce a marked increase in the aorticopulmonary shunt and may of itself lead to cardiac failure. Instances of cardiac failure have been known to occur a few years after a primarily successful Potts' operation. The best operative results are obtained after the age of two years. Blalock(6) expresses his opinion in this manner, "If a child under two years has a 50 per cent chance of surviving, the operation should be postponed until that age is reached." In milder cases, it is ideal to wait until the age of six years.

Subclavian-Pulmonary Artery Anastomosis. Blalock-Taussig Operation. After conception of the operation in cooperation with Helen Taussig, Blalock performed the first subclavian pulmonary artery anastomosis for the tetralogy of Fallot in 1945(5, 6, 7, 40) Blalock(6) called attention to the fact that, "The subclavian branch of the innominate artery when transposed makes a much more satisfactory angle with its parent vessel than is present when the subclavian branch of the aorta is used." Although a satisfactory anastomosis can be performed with the subclavian branch of the aorta despite the tendency to kinking of the vessel at its origin from the aorta, we prefer to use the subclavian branch of the innominate artery. A right thoracotomy is therefore employed when the aorta descends nor-

mally on the left side, and left thoracotomy when there is a right aortic arch and a right descending aorta.

An anterolateral incision in the third interspace with division of the third and second costal cartilages gives adequate exposure. This approach interferes less with respiratory function during operation and with the collateral circulation to the lungs than does a posterolateral incision through the fourth interspace or bed of the fourth rib.

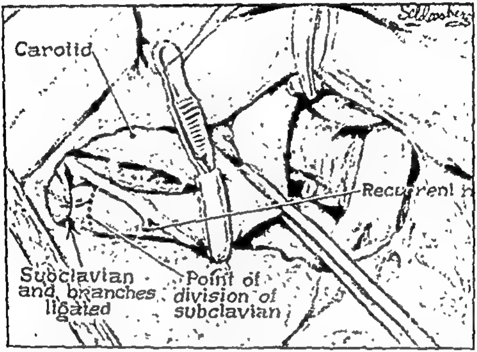

Fig 3-12. The Blalock-Taussig operation The azygos vein has been divided and the superior vena cava elevated *The left pulmonary artery has been exposed The ligature at the left of the* [illegible] has been tied over the subclavian artery and its first branch As Blalock has pointed [illegible] ll be less danger of the ligatures [illegible] 948.)

After the pleura is opened, the pulmonary artery is first exposed in order to determine whether it is of sufficient size to make an anastomosis. The innominate artery is then exposed and freed from surrounding tissue up to its division into the carotid and subclavian arteries. This exposure is facilitated on the right side by ligation and division of the azygos vein which permits the superior vena cava to be displaced anteriorly and medially with greater ease (Fig. 3-12). The vagus nerve and its recurrent laryngeal branch are then exposed and protected from injury during subsequent manipulations. The subclavian artery is then ligated as far distally as possible. It is usually advisable to ligate separately the first branch of the subclavian artery, usually the vertebral artery, and the subclavian artery just distal to this branch in order to obtain additional length and to obviate the possibility of a single ligature, just proximal to the first branch, slipping off. A rubber-shod bulldog clamp is then applied to the subclavian artery at its origin and the ends of the clamp tied with heavy silk. The subclavian artery is then divided just proximal to its first branch.

After the subclavian artery has been divided, its free end is trimmed of adventitia; if it is a small vessel, it is cut obliquely in order to increase the

During the suturing the vessels are kept in the right position by an assistant. Number 5-0 Deknatel silk is used for suture material. First the *posterior wall of the anastomosis is sutured with a continuous row of everting* mattress sutures, set one to two millimeters apart (Fig. 3-15). When the row is finished, the suture is drawn taut, care being taken to exert a uniform tension on each stitch in the suture line. Each of the ends is tied to an interrupted suture. The anterior wall of the anastomosis is finished in a similar way. This suture line should be interrupted at least once. When the anas-

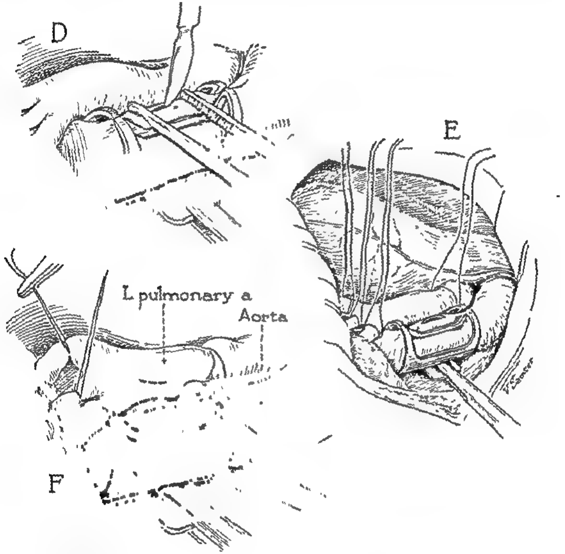

Fig. 3-17 Steps in the technic of an aortic-pulmonary anastomosis (From Potts, W. J Ann. Surg, 130 342, 1949)

tomosis has been completed, the ligatures around the branches of the pulmonary artery are loosened first, a slight ooze from the suture line always occurs but soon stops. The Blalock clamp on the pulmonary artery is then loosened and finally the clamp on the subclavian artery is slowly opened and removed, if no leak is seen in the suture line. A continuous thrill over the pulmonary artery will indicate that the anastomosis is functioning.

Should the pulmonary artery not be of sufficient diameter for such an anastomosis, the chest may be closed and the operation can be carried out

on the opposite side three months later. However, if the patient's condition requires immediate relief, the subclavian artery should be anastomosed to the end of the divided pulmonary artery. An end-to-end anastomosis of this type allows the blood to pass to one lung only, and the consequences of thrombotic occlusion of the anastomosis are more serious than in the end-to-side type.

Aortic Pulmonary Artery Anastomosis. Potts' Operation. After Potts devised the aortic pulmonary anastomosis in 1945(32), the operation was done on either the left or the right side, depending on the course of the aorta(30). The right-sided anastomosis has now been abandoned because of the unfavorable anatomic relations on this side, where the bronchus passes between the pulmonary artery and the aorta. Furthermore, the vessels run at a 90 degree angle to each other on the right side.

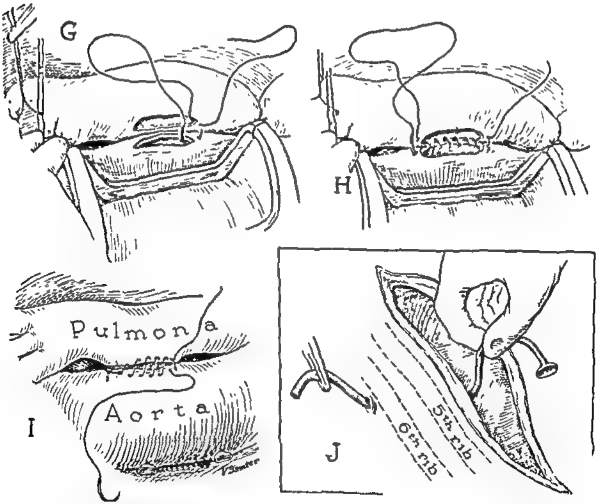

Fig 3-17 (cont) Steps in the technic of an aortic-pulmonary anastomosis The procedure is described in the text (From Potts, W J Ann. Surg, 130.342, 1949)

The necessary exposure is best obtained through a posterolateral incision. The chest is entered through a left posterolateral incision in the fourth intercostal space or through the bed of the resected fourth rib. The pulmonary artery and its branches are dissected free as in preparation for a Blalock-Taussig anastomosis. The mediastinal pleura is incised over the aorta and drawn laterally by traction sutures. The aorta is mobilized by

ligating and dividing a number of intercostal arteries, usually four to six, at the level where the aorta is crossed by the pulmonary artery.

Doubly encircling ligatures of oiled No. 8 silk are placed around the pulmonary artery and its branches, but not drawn taut as yet. A Potts' clamp (Fig. 3-16) of suitable size is now applied over the segment of the aorta where the anastomosis is to be made. First the lower half of the clamp is slipped beneath the vessel, then the upper half is brought into position and the clamp is tightened, clamping off the part of the aorta adjacent to the pulmonary artery, yet still allowing blood to pass through the rest of the aorta. The clamp should be tightened to a degree just sufficient to provide hemostasis without crushing the vessel wall.

After the adventitia has been removed from the occluded portion of the aorta, a small opening is cut in the middle of the occluded segment with a small, round-ended, long-handled knife (Fig. 3-17 D). The opening is enlarged with fine-pointed, angled scissors to the length of 6 mm. To facilitate the suturing, the incision is placed exactly in the middle so that both lips of the aortic wall will be long enough for the placing of sutures. Before the pulmonary artery is occluded, the lungs are expanded and aerated for some minutes. The ligature around the superior branch of the pulmonary artery is tied to the caudad flange of the clamp, while the ligature around the main pulmonary artery is tied to the cephalad flange (Fig. 3-17 E, F). The pulmonary artery is then incised in the same manner as the aorta, and the opening enlarged with angled scissors to equal the aortic incision.

The anastomosis is performed with No. 5-0 Deknatel silk. First, the posterior wall is sutured with a running over-and-over suture, the stitches being set 1 mm. apart and 1 mm. from the edges (Fig. 3-17 G, H). After every stitch the suture is drawn up gently to coapt the edges. The posterior suture is begun and ended with an interrupted suture, to which the ends of the continuous suture are tied. In the anterior wall a continuous everting mattress suture is used, bringing intima to intima. This is probably preferable to the running suture illustrated in Figure 3-17I. The suture is not drawn taut until the suture line is completed. The ends are tied to interrupted sutures.

As following a Blalock-Taussig anastomosis the ligatures around the branches of the pulmonary artery are loosened first, then the proximal pulmonary artery ligature. When oozing from the suture line has stopped, the aortic clamp is slowly unscrewed while the anastomosis is inspected for leakage and the anesthetist keeps close watch on the blood pressure. Closed intrapleural drainage is established through a separate stab wound (Fig. 3-17J) and the chest wall is closed anatomically in layers.

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4

CARDIAC SEPTAL DEFECTS AND OPEN CARDIOTOMY

HYPOTHERMIA AND THE HEART-LUNG MACHINE

John H. Gibbon, Jr., and Hans C. Engell

ATRIAL SEPTAL DEFECTS

Atrial septal defects, either isolated or in combination with other cardiac malformations, are, next to ventricular septal defects, the most frequently reported congenital cardiac anomaly discovered at postmortem(20). Until recently, in clinical reports the incidence of atrial septal defects has not been as great, since in many cases they do not produce symptoms during life(2, 4, 9, 10). Furthermore, if they do produce symptoms, they have frequently been misdiagnosed. The increasingly widespread employment of cardiac catheterization will undoubtedly increase the number correctly diagnosed during life.

Anatomy. All transitions are seen from small defects without physiologic significance to defects where only a sickle-shaped rim is left between the atria. In some instances, the septum will appear as a fenestrated membrane with numerous openings of various sizes. The occurrence of atrial septal defects combined with pulmonary stenosis has been mentioned in the preceding chapter. Atrial septal defects may also be found in combination with mitral stenosis, a combination of lesions referred to as Lutembacher's syndrome(1). In this syndrome, the pulmonary artery is enormously enlarged. Atrial septal defects are also not infrequently associated with the abnormal opening of one or more pulmonary veins into the right atrium or at the border line between the atria.

Pathologic Physiology. When the defect is the sole anomaly, or is associated with mitral stenosis, the shunt will be principally from the left to the right atrium. The blood shunted through the defect, sometimes several times the aortic blood flow, will recirculate through the lungs and thus result in increased work for the right side of the heart. If the pressure is raised in the right atrium, the shunt may reverse causing a decrease in oxygen saturation of the arterial blood, which may prove disastrous to the myocardium of a heart near the point of right-sided failure. Thus, one should administer blood transfusions cautiously during operations on atrial septal defects.

Diagnosis. The symptoms are not specific. They consist usually of dyspnea on exertion, palpitation, and fatigue. A harsh, systolic murmur usually best heard in the left second and third interspace near the sternum will be characteristically present whenever there is a left to right shunt of any magnitude. In large shunts, roentgenograms will reveal great enlargement

of the right atrium and enormous hypertrophy of the right ventricle. The pulmonary vascular markings will be accentuated and there will be increased hilar pulsations.

On cardiac catheterization, the diagnosis will be established by the passage of the catheter through the defect from the right to the left atrium, or, more usually, the demonstration of a shunt of arterialized blood into the right atrium. It should be kept in mind that such a shunt may be due to an abnormal opening of pulmonary veins into the right atrium.

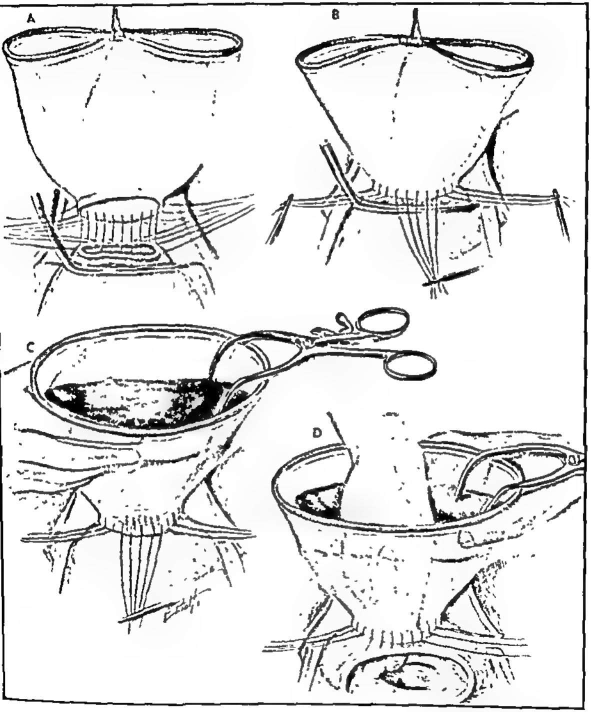
Prognosis and Indications for Operation. Many patients will live to an advanced age. The average duration of life is between 30 and 40 years (19, 4, 9). The chief cause of death is right-sided heart failure. With the technics presently available, operation should be confined to young individuals with progressive symptoms. As experience and technical equipment develop, the indications for operation will naturally be widened to include patients with slight symptoms who are still well compensated.

OPERATIVE METHODS

Numerous methods for closure of septal defects have been described in recent years, some have been used in experimental surgery only, and some have been applied clinically as well. The following descriptions of operative technic will be confined to those which have been used successfully in human patients. The procedures may be divided into the blind methods, in which the defect is located and sutures are placed by palpation, and the open methods in which the defect is closed under direct vision. In the open methods the heart is temporarily isolated from the circulation either by utilizing hypothermia to permit occlusion of the venous inflow for a brief period of time, or by diverting the venous return to the heart through an extracorporeal heart-lung apparatus which maintains the cardiorespiratory functions.

Gross's "Well" Technic (14). This ingenious method of closing interatrial septal defects takes advantage of the low, hydrostatic pressure in the right atrium. A posterolateral approach through the right fifth intercostal space is used. The pericardium is opened by a longitudinal incision parallel and anterior to the phrenic nerve. Two traction sutures are placed in the auricular wall at the caudad and cephalad ends of the proposed opening in the atrium. With traction on these stay sutures, a noncrushing clamp is placed on the atrial wall so as to isolate temporarily from the main atrial chamber the line of the proposed incision. The technic from this point on is illustrated in Figure 4-1 A conical rubber well is sutured to the margins of the incision. The clamp is then removed and the blood allowed to rise up in the well. Before doing so, the interior of the well is flushed with 0.4 per cent heparin in physiologic saline solution During the subsequent course of the operation, 2 ml of a 1 per cent heparin solution are added every two minutes. The atrial defect is palpated to determine its size and location. The defect is closed by utilizing plastic material (Ivalon sponge) as a graft or by direct suture. The latter method is best if it can be applied, but when some of the pulmonary veins open into the right atrium, plastic material

must be used to create a septum which will divert all the pulmonary venous blood into the left atrium The direct suturing, or the suturing in place of plastic material to close the defect, is carried out through the open well guided by the palpating finger. Utilizing this method, Gross and Kirklin(15)



Courtesy Dr Robert Gross

Fig 4-1. Illustration of the technical steps in the Gross well technic for the repair of atrial septal defects

have completely closed a number of interatrial defects in patients with good results. It is difficult to say at this time whether the method will continue to be used or whether simpler procedures will prove better. As in all closed methods, the sutures must be placed by palpation rather than under direct

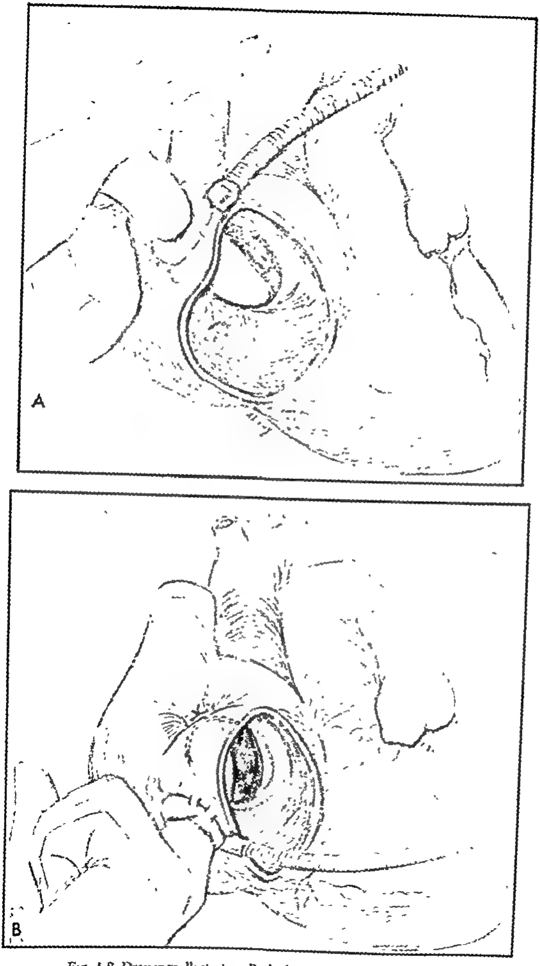
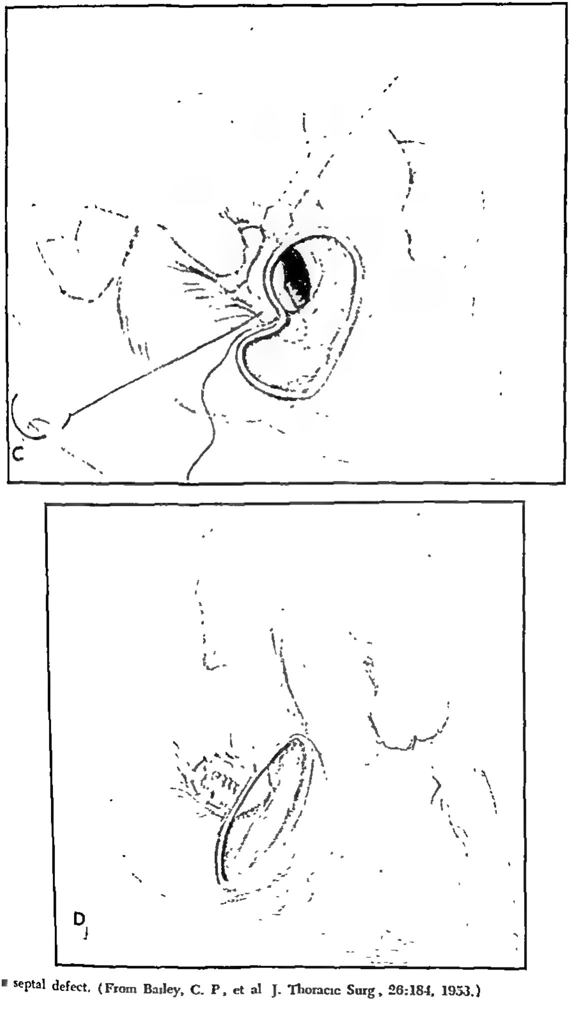


Fig 4-2 Drawings illustrating Bailey's technic of inverting the atrial wall to close



■ septal defect. (From Bailey, C. P., et al. J. Thoracic Surg., 26:184, 1953.)

vision. In addition, the size of the well necessarily hampers the manipulation of the needle holder and other instruments.

Bailey's Inversion of Atrial Wall Technic(3). Cohn(8) created atrial septal defects in animals and then closed the defects by suturing the invaginated wall of the right atrium to the margins of the defect. He then cut the wall of the atrium just beyond the line of suture to the defect and finally repaired the opening in the atrial wall. Bailey has modified this procedure in patients by not dividing the invaginated atrial wall. He has termed this procedure atrio-septo-pexy. Exposure is obtained by an anterolateral incision in the right fourth interspace with the patient in the supine position. The fourth and fifth costal cartilages are divided. The pericardium is opened as usual by an incision anterior and parallel to the phrenic nerve. The septal defect is then explored with an ungloved index finger inserted into the atrium through the stump of the amputated right atrial appendage, similar to the procedure employed in finger fracture valvotomy for mitral stenosis. Hemostasis is obtained by a purse-string suture around the auricular stump over the exploring finger. A Rumel-Belmont tourniquet may be used as shown in Figure 4-2 if desired to keep the purse string taut. The atrial wall is then invaginated and sutured to the margins of the septal defect with interrupted mattress sutures (Fig. 4-2). After the suturing is completed, the index finger is withdrawn and the stump of the appendage ligated. At the completion of the procedure, the right atrium is converted somewhat into the shape of a doughnut. Blood from the superior and inferior venae cavae passes around the portion of the atrial wall which has been used to close the defect and thus reaches the tricuspid valve. The procedure is also adaptable to cases where there is an anomalous drainage of the right pulmonary veins into the right atrium. In such cases it may be possible to suture the invaginated atrial wall to one side of the defect so as to drain these pulmonary veins through the defect into the left atrium at the same time closing the communication between the right and left atria. The above described method of Bailey's cannot be applied to all cases. If the defect is very large, invagination of so large a portion of the atrial wall may result in some obstruction to the blood flow from the superior and inferior venae cavae. Similarly, in small children there may be insufficient dilatation and enlargement of the atrial wall to permit its invagination without similar interference with the blood flow from the cavae. It is, however, a suitable method for the repair of small to medium sized defects in older children or adults with considerable right atrial dilatation and hypertrophy.

The Björk-Søndergaard Purse-String Method(6). With the patient lying on the left side, a right posterolateral, periscapular incision is made. The pleural cavity is entered through the fourth interspace or the bed of the fourth rib. The pericardium is opened anterior and parallel to the right phrenic nerve. The venae cavae are dissected free at their junctions with the right atrium. The groove between the right and left atrium is dissected out beginning between the superior vena cava and the right superior pulmonary vein. While the upper part of the groove can always be dissected quite deeply, only a little dissection can be done between the inferior pulmonary vein and the inferior vena cava if the septal defect is so large that

little or no septal rim remains between the right and left atrium. The importance of this dissection is to avoid obstruction of the venae cavae and pulmonary veins when the suture placed around the perimeter of the atrial septum is drawn taut. A purse-string suture is now placed around the base of the right auricular appendage. The tip of the appendage is amputated and the left index finger is introduced through the stump of the appendage into the right atrium to guide the needle which will carry a suture around the perimeter of the interatrial septum. A long, thin, curved needle is introduced through the right atrial wall at the right side of the root of the aorta behind the right coronary artery. Under the guidance of the finger within the atrium, the needle is passed close to the aorta subendocardially in the rim of the septum down through the upper anterior portion of the interventricular septum and out through the left atrial wall behind the inferior vena cava (Fig. 4-3 A) The two ends of the thread are then drawn taut over a piece of gelfoam. When the suture is tied, the finger within the atrium can feel the septum and part of the atrial wall drawn down to the interventricular septum (Fig. 4-3 B). As the bundle of Hiss coming from the atrioventricular node in the right atrium passes through the posterior part of the interventricular septum, the needle should be guided subendocardially on the left side of the posterior part of the interventricular septum.

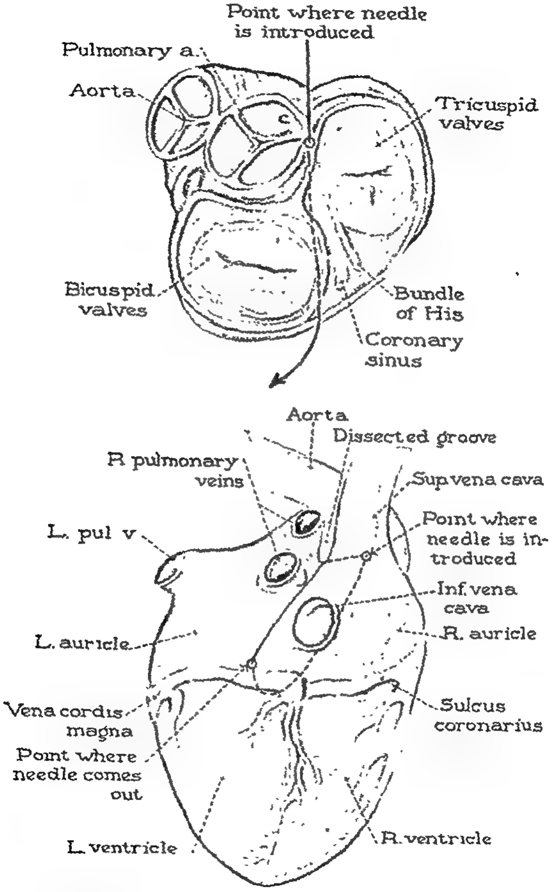
This method has just recently been introduced, but the results achieved with it to date are very promising. It has the disadvantage that it cannot be used in patients with anomalous drainage of the pulmonary veins and, like all the closed methods, it is impossible to be sure by direct vision that the defect has been completely closed.

VENTRICULAR SEPTAL DEFECTS

To date, no case of demonstrated complete closure of a ventricular septal defect with prolonged survival has been reported in man. However, increasing experience with hypothermia and further perfection of the heart-lung machine seem to herald the day when this goal will be achieved. The problems involved, therefore, should be discussed briefly.

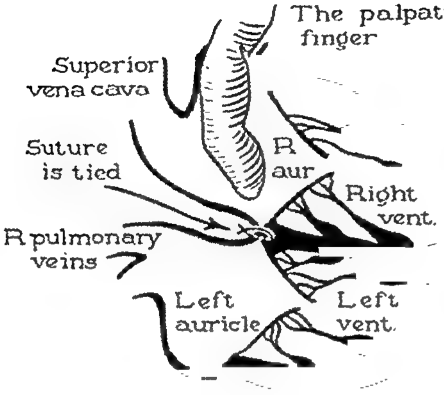
Anatomy. Ventricular septal defects not associated with other malformations most frequently occur in the upper part of the septum membranaceum. In the right ventricle, the defect is partly hidden by the medial cusp of the tricuspid valve This cusp and its chordae tendineae are fibrotic and retracted as a result of the jet of blood through the defect. On the left side, the defect is immediately below the aortic valve. The majority of the defects are under 1 cm. in diameter. The edges of the defect are thin and membranous and even the larger defects can be closed without tension by simple suture.

Pathologic Physiology. In isolated ventricular septal defects, the shunt will be constantly from the left to right because of the greater pressure in the left ventricle. In large defects, the pressure in the right ventricle and the pulmonary artery increases, leading to secondary changes in the pulmonary vessels which result in an increased pulmonary vascular resistance and increased right ventricular pressure(13), and a mixed shunt may occur.



A

Fig. 4-3. The Björk-Sondergaard purse-string method of closing atrial septal defects. A, diagrammatic illustration of the method. See text for details. (From Björk, V. O., and Crafoord, C. J. Thoracic Surg., 26:500, 1953.)



B

Fig. 4-3 (cont.). B, showing the effect of drawing up upon and tying the suture. (From Björk, V. O., and Crafoord, C. J. Thoracic Surg., 20:300, 1953.)

Diagnosis. In isolated ventricular septal defects giving no clinical symptoms, the only physical findings consist of a harsh systolic murmur and thrill over the precordium. The murmur is usually best heard in the third and fourth interspace to the left of the sternum. The heart is generally of normal size with a slight dilatation of the truncus arteriosus. The diagnosis is established by cardiac catheterization demonstrating an increased oxygen content of the blood in the outflow tract of the right ventricle and in the pulmonary artery.

Prognosis. Many isolated interventricular septal defects never cause any physical disability. Even when an arteriovenous shunt can be demonstrated, the first symptoms often appear late in life. Where bacterial endocarditis does not complicate the case, the prognosis will depend upon the degree of hypertension in the right ventricle.

OPEN CARDIOTOMY WITH HYPOTHERMIA

The term hypothermia in relation to clinical cardiac surgery is applied to the reduction in body temperature to a point not below room temperature, i.e., 21° C. Mild degrees of hypothermia, reducing body temperature 4° or 5° C., have been used during operations on the heart in cyanotic children to diminish the body's requirement for oxygen. More pronounced degrees of hypothermia, to the range of 23° to 26° C., are necessary for open cardiotomy with temporary complete occlusion of both venae cavae. The safe time limit probably does not exceed eight to nine minutes under these circumstances and shorter periods of time are obviously preferable. With

longer periods, irreversible anoxic damage to the brain and heart may occur. Possibly the period of safe occlusion may be somewhat extended by transfusion of moderate amounts of oxygenated blood to the brain and coronary arteries. Bigelow has carried out the most extensive physiologic investigation of this subject in experimental animals(5, 7, 16).

Swan has had the most extensive clinical experience with open cardiotomy and hypothermia in human patients. He has reported the closure of four atrial septal defects in human patients with one death by this method(22). He also has studied the metabolic changes occurring during hypothermia(23), and the development of ventricular fibrillation at temperatures of 23° to 26° C., which has been a major threat. Electric shock under these conditions has usually been ineffectual. Swan emphasized the importance of marked hyperventilation throughout the cooling period to prevent an increase in carbon dioxide tension. He also observed a fall in the serum potassium and found that ventricular fibrillation could be arrested by injecting potassium chloride directly into the coronary arteries and regular cardiac action could then be established by injecting calcium chloride in the same manner. Recently prostigmin has been found useful in preventing cardiac irregularities during hypothermia(21).

All methods, employing open cardiotomy on the right side of the heart in the presence of septal defects, involve the danger of air entering the left ventricle, and hence the aorta, with fatal air embolism of the coronary arteries. The technic of avoiding air embolism employed by Swan(22) will be described below Another method of avoiding air embolism will be described later in discussing the heart-lung machine.

Anesthesia and Hypothermia. Anesthesia is established with thiopental and ether, and the trachea is intubated, before placing the patient in a bath of ice water. A continuous electrocardiographic tracing is started before cooling. The brachial artery pressure is measured with an intra-arterial catheter, as indirect measurement is impossible when arterial spasm occurs during cooling. Body temperature is recorded from a thermocouple in the rectum. During the cooling phase the patient is hyperventilated, so that the pH in the arterial blood rises to 7.6 or even 7.7. If cardiac irregularities occur, 1 mg. of prostigmin is given intravenously. When the body temperature has fallen to approximately 30° C., the patient is removed from the ice bath and placed on the operating table.

The time required for the rectal temperature to fall to 30° C. is quite variable. Infants require the shortest period. Young children from 5 to 10 years of age require about 30 minutes; adults up to one hour and a half, depending upon their size and the amount of subcutaneous fat. After the patient is removed from the bath and placed on the operating table a further drop in body temperature of 3° to 6° C. will occur. After the operation is finished, the patient is immersed in a bath of warm water to hasten the return to normal body temperature.

Operative Technic. A trans-sternal incision entering both pleural cavities through the fourth interspace with the patient in the supine position as described in the preceding chapter gives an excellent exposure of the entire heart. After widely opening the pericardium, the venae cavae are exposed above and below the heart, so that they may be occluded by slings of um-

bilical tape. Stay sutures are placed along the planned incision in the right atrial wall. Now the slings around the venae cavae are drawn taut. After 30 seconds when the heart has emptied itself, a noncrushing clamp is placed across the aorta, 2 or 3 cm. distal to the aortic valves, and 5 ml. of a 1:4,000 prostigmin solution is injected into the aorta central to the clamp. The heart rate immediately decreases to 4 to 10 beats per minute and cardiac irritability is greatly decreased. The aortic clamp is then removed and replaced over the base of the aorta occluding the coronary arteries. One minute has now elapsed since occluding the venae cavae. The right atrium is now widely opened and the atrial septal defect is closed by a continuous suture of 4-0 Deknatel silk. Just before tying the final knot of the continuous suture, the chest is flooded with Ringer's solution so that the entire heart is submerged. The approximated margins of the septal defect are then slightly spread apart by the opened blades of a hemostat. When no further bubbles of air escape, the silk suture is tied and the ends cut. A noncrushing clamp is then applied to the margins of the atrial wound while the heart is still submerged. The clamp occluding the aorta is first opened, then the clamp on the superior vena cava is removed, and, one-half to one minute later, if heart action appears satisfactory the clamp on the inferior vena cava is taken off. The cardiotomy wound is now closed with a continuous running suture of 4-0 or 5-0 Deknatel silk reinforced with interrupted stitches where necessary. As stated above, after the chest wound has been closed and closed drainage of both pleural cavities established, the patient is placed in a bath of warm water to hasten the return to normal body temperature.

OPEN CARDIOTOMY WITH THE HEART-LUNG MACHINE

Closure of previously created ventricular septal defects in dogs has been performed successfully using a heart-lung machine to shunt the circulation while the right ventricle was opened. This method is probably the one most likely to be employed in the future on human patients, especially as most patients with isolated ventricular septal defects requiring operation are adults who do not withstand hypothermia as well as infants.

In 1939, the first experiments were reported of prolonged survival of animals in which the circulation through the heart and lungs was completely stopped by clamping the pulmonary artery for as long as 20 minutes while the cardiorespiratory functions were maintained by a heart-lung apparatus(11). Since then, several types of apparatus have been developed by a number of investigators. The present model in the Jefferson Hospital in Philadelphia has been used with consistent success and with low mortality in experimental animals(18). In May 1953, closure of an atrial septal defect was performed under direct vision while the cardiorespiratory functions were maintained entirely by the apparatus for 26 minutes. The patient, an 18-year-old girl, is in good health more than one year after the operation(12). Cardiac catheterization three months postoperatively demonstrated complete closure of the defect. Much work remains to be done to elucidate the physiologic problems involved in the artificial maintenance of cardiopulmonary functions over prolonged periods before the apparatus can be regarded as one of the standard tools of intracardiac surgery. Neverthe-

less, a short description of the principles and use of the heart-lung apparatus is appropriate.

The heart-lung machine includes collecting chambers into which the vena caval blood and the cardiac venous blood is drawn by suction and pumps which deliver the venous blood from these chambers to the battery-type screen oxygenator(17) where the blood stream is converted into a thin film exposed to oxygen. In the oxygenator, oxygen is absorbed and carbon dioxide eliminated. The blood is pumped back to the aorta via a systemic artery.

The diagram (Fig. 4-4) outlines the essential parts of the heart-lung machine. From cannulae in the venae cavae, the blood is diverted to the negative pressure chamber A. The blood is then propelled by pump C to the oxygenator pump G. An electronic device E controls the rate of pump C,

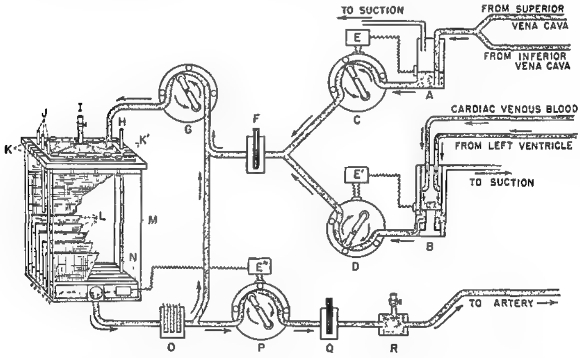


Fig. 4-4 Diagram of the extracorporeal blood circuit in the heart-lung machine For detailed description, see text.

so that a constant level of blood is maintained at the bottom of the chamber A. The blood from the vent tube in the left ventricle (see below), and the cardiac venous blood which is mixed with air bubbles, is drawn into a separate negative-pressure collecting chamber B, where the blood is defoamed as it passes down the inner walls of a plastic cylinder. This blood is conveyed to the oxygenator pump G by a separate pump D, the speed of which is also regulated by a level control device E'. Blood leaving the venous pumps passes through the oxygenator pump G. This pump draws blood from the bottom of the oxygenator through a by-pass as well as from the venous pumps.

The flow through pump G is fixed at a constant rate which is greater than the maximum flow rates through the venous pumps C and D. By maintaining a constant flow rate over the screens, L, of the oxygenator, the volume of blood held on the screens is kept constant. This avoids changes

in the subject's blood volume incident to changes in flow rate through the extracorporeal blood circuit.

The blood enters the top of the oxygenator and passes down through the slits, KK', in a film over the screens, L, enclosed in the plastic case, M. The screens are held in position at the bottom of the case by a plastic block, N. Oxygen is blown into the plastic case through the perforated tube, H. Oxygen and carbon dioxide escape through the three tubes, J. The closed vent, I, permits air bubbles to be evacuated from the top of the oxygenator when filling. The blood is pumped from the bottom of the oxygenator to the subject's aorta by the pump, P. This pump is controlled by the electronic device, E", which maintains a constant level of blood in the bottom of the oxygenator at all rates of flow. Before the blood enters the subject's vascular system, it is passed through a fine mesh filter, R.

Additional devices have been incorporated in the extracorporeal circuit for the continuous recording of the pH of the blood, O, and the temperature, F and Q. The oxygenator has been constructed in two sizes, a smaller one capable of fully saturating with oxygen 2,000 ml. per minute of venous blood 65 per cent saturated, and a larger model which allows the saturation of 4,500 ml. of venous blood per minute. Depending on which size oxygenator is used, 1,400 or 1,750 ml. of donor blood is required to fill the apparatus prior to a perfusion.

Operative Procedure. With the patient in the supine position, the thorax is opened through an inframammary, transverse incision in both fourth interspaces transecting the sternum. With a rib spreader separating the divided sternum, the upper half of the costal cage is elevated giving a wide exposure of the heart and great vessels. Meticulous hemostasis must be observed at all times. The following vessels are dissected free: the left subclavian artery, the superior vena cava caudad to the azygos vein, and the inferior vena cava just below the right atrium. The pericardium is widely opened and all small vessels in the cut edges are ligated. Heparin, 2 mg. per kg. of body weight is then given to the patient. The left subclavian artery is ligated distally, clamped proximally and opened between the ligature and the clamp. The cannula which will return the oxygenated blood to the aorta is inserted in a central direction and secured in the central part of the subclavian artery after both the cannula and the tubing to the apparatus have been filled with blood (Fig. 4-5). The tubing is securely clamped in the operative field. A Tygon cannula is inserted into the superior vena cava through the wall of the right atrium, and a similar cannula is inserted into the inferior vena cava through the right auricular appendage (Fig. 4-5). Both cannulae are secured by purse-string sutures. Now partial extracorporeal circulation is begun. First the clamp on the tube to the artery is removed, then the clamps on the venae caval tubes. When the blood flowing from the cavae raises the level in the venous reservoir, the level control mechanism will automatically start the pumps. When the partial perfusion is functioning satisfactorily, heavy silk ligatures are tied around both cavae over the enclosed cannulae. The ligatures are tied over small segments of rubber tubing (Fig. 4-6) to facilitate cutting these ligatures at the end of the perfusion without injuring the vein wall. Thus all the systemic venous blood passes to the extracorporeal circuit instead of to the right atrium.

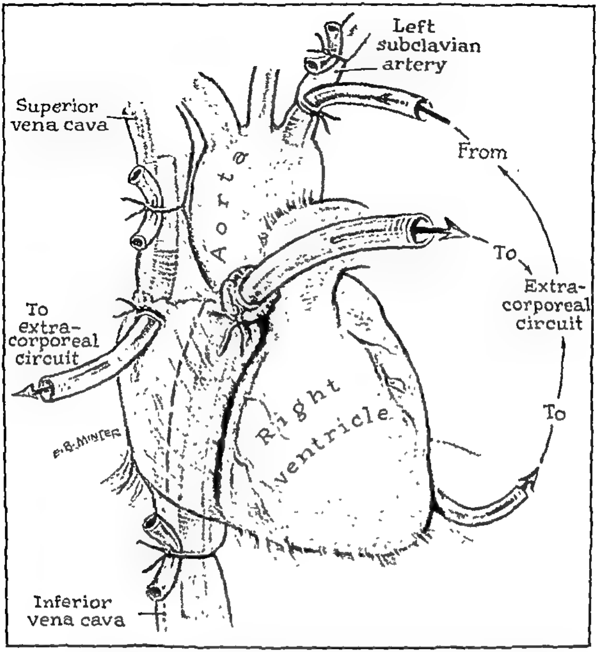


Fig 4-5 Drawing illustrating cannulation of vessels and left ventricle when employing the heart-lung machine The site of the proposed incision in the right atrium is shown by a dotted line to the left of the cannula passing through the right atrium into the inferior vena cava.

An open cardiotomy in the right atrium exposed this chamber to atmospheric air. In the presence of either an interatrial or interventricular septal defect air may reach the left ventricle and be ejected into the aorta resulting in air embolism of the coronary arteries. Such embolism promptly results in cardiac arrest or ventricular fibrillation. To avoid this hazard, a low pressure vent is established in the left ventricle so that the pressure in the ventricle will never rise high enough to open the aortic valves. A Tygon tube 5 mm. in diameter is inserted into the left ventricle by means of a stab wound in the apex (Fig. 4-5). This tube conducts blood and air to the collecting chamber B (Fig. 4-4), into which the cardiac venous blood which is continuously aspirated from the opened heart is also returned. Using this vent tube air embolism has never occurred in operations upon patients or animals.

Fig 4-6 Photograph taken at operation of closure of an isolated ventricular septal defect in a 38-year-old man The heart-lung machine was used. The right ventricle has been opened and the ventricular defect is being closed with interrupted stitches

It is possible to keep the interior of the heart sufficiently dry, by aspirating the cardiac venous blood, to allow the exact suturing of an atrial or ventricular septal defect under the guidance of direct vision (Figs. 4-6 and 4-7). Complete closure of large atrial septal defects can be accomplished without the use of a graft.

Right atrial wounds are closed by a continuous over-and-over suture of 5-0 Deknatel silk. Right ventricular wounds are closed with a continuous

everting mattress suture oversewn with an over-and-over suture. It has been observed in animal experiments that omitting the mattress suture in the ventricular wall may result in an aneurysmal dilatation of the scar.

Fig. 4-7. Another photograph taken at the same operation as in Figure 4-6 showing the closed ventricular septal defect The absence of obscuring blood in the operative field is evident. This patient died five hours after operation with atelectasis of both lower lobes of the lungs.

As soon as the perfusion is terminated, protamine sulfate, equal in amount to the heparin which had been given, is administered intravenously. The solution, approximately 200 ml., should be given as fast as possible, i.e., in 10 or 15 minutes, without producing a drop in blood pressure. In spite of

the protamine sulfate, a diffuse oozing from the thoracic cavity of 1,000 to 1,500 ml. of blood must be anticipated in the first three to four hours following the operation. Closed drainage of both pleural cavities through separate stab wounds should always be done.

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5

INTRACARDIAC SURGERY FOR ACQUIRED VALVULAR HEART DISEASE

John C. Jones and Bert W. Meyer

MITRAL STENOSIS

In 1948, Bailey(3) and Harken(18), working independently, described their technic for relieving the obstruction of the mitral valve caused by rheumatic fever. Subsequent work by these(5, 6, 17) and other authors(9, 12, 13, 19, 20) perfected the technic and established mitral "commissurotomy," "valvuloplasty," or "valvotomy," as it is variously called, as a sound surgical procedure resulting in a high percentage of favorable results in properly selected cases. Thus a vast new field in cardiac surgery was opened, stimulating great interest in the surgical treatment of other valve lesions, as well as technics in hypothermia and extracorporeal circulation which now enable surgeons to open the heart and operate on the heart valves under direct vision in a bloodless field. The chief disadvantage to the procedure at the present time is that it is done blindly and all manipulations of fracturing or cutting the valve must be done by feel. This new phase in intracardiac surgery was made possible not only by the recent advances in surgical methods and anesthesia technics developed in the treatment of congenital cardiovascular diseases in the previous 10 years, but also by the surgical pioneers who attempted surgery on the beating heart, but lacked the present day surgical knowledge to carry it to a successful conclusion. Historically, the concept of intracardiac surgery is not new. Brunton(10) of England in 1902 reasoned that mitral stenosis due to rheumatic fever was a mechanical defect which could be corrected only by surgery. Allen and Graham (1) in 1922 described their experimental work with a cardiovalvuloscope which had an attached cutting instrument to open the mitral valve, and, in 1924, they reported their unsuccessful clinical results(2). The ease of access to the mitral valve through the auricular appendage, however, was demonstrated. Cutler, Levine, and Beck(14), in 1924, attacked the mitral valve through the left ventricle with a specially devised knife or valvulotome and attempted to punch out portions of the mitral valve, thereby producing a regurgitation. The concept of commissural closure by the rheumatic fever process as put forth by Bailey and Harken was not appreciated by them. Because of the prohibitive mortality, their operative attempts were ultimately abandoned. Souttar(25), in 1925, carried out a successful commissurotomy, much the same as we do it today, but no further cases were reported by him, even though the patient was improved by the operation. A period of over 20 years then elapsed, during which time little was done in the way of developing the field of intracardiac surgery. Smithy(23, 24)

in 1948 and 1950 reported on his studies in the treatment of mitral and aortic valvular disease due to rheumatic fever. As did Cutler et al., he employed the transventricular route, and used a modified biopsy punch to cut out pieces of the valve leaflets. Valuable information was gained from his work, but he, too, did not appreciate the disastrous effects of creating a mitral regurgitation by his procedure.

Physiologic Considerations. Along with the great interest in the field of intracardiac surgery, there has been a parallel interest by the internists in the field of pathologic physiology as it relates to cardiac disease. Catheterization studies have yielded much information about pulmonary circulation, but there still remain many problems yet to be solved, among these being the relationship of pulmonary blood flow to the development of pulmonary hypertension, the role of pulmonary hypertension in the development of pulmonary arteriolar changes, and the degree of reversal of these pulmonary vascular changes once the obstruction at the mitral valve is relieved. Normally, the pulmonary artery pressure ranges from 8 to 15 mm. Hg, whereas the pulmonary capillary bed pressure ranges from 6 to 12 mm. Hg. The pulmonary venous or left atrial pressures cannot be measured directly by catheterization, but the pulmonary capillary pressures or wedge pressures are believed to reflect the pressures in these areas. When obstruction at the mitral valve develops in the rheumatic fever patient one of two changes occurs: the pressure may rise to overcome this resistance, or the cardiac output will be diminished. Using pressure-flow relationships and applying standard hydraulic formulas, Gorlin(15) has estimated that the mitral orifice must be decreased to 2.5 sq. cm. from a normal of 4 to 6 sq. cm. before any change in the hemodynamics becomes evident. If the valve orifice is smaller than 2.5 sq. cm., then there occurs an elevation of the pulmonary artery pressure, and symptoms of pulmonary hypertension ensue, such as cough, hemoptysis, dyspnea, wheezing, and pulmonary edema. A valve orifice which measures 1.5 sq. cm. or less causes marked symptoms of pulmonary hypertension and recurrent bouts of congestive heart failure. If the pulmonary hypertension has persisted for some time, then sclerotic changes in the arterioles of the pulmonary vascular bed develop, which further increase the pulmonary artery pressures, and further decrease the cardiac output. Eventually, signs of right heart failure appear, with increased venous pressure, hepatomegaly, peripheral edema, and ascites. If Gorlin's estimation of the mitral valve orifice is correct, then to achieve the maximum improvement, the goal of the surgeon is to create an orifice which is 2.5 sq. cm or larger in size.

Pathologic Considerations. If the optimum improvement is to be obtained after commissurotomy it is imperative to have a cardiovascular system which has not been too severely damaged by the original rheumatic fever process, or by the degree of mitral valve pathology (thickening and calcification) and the length of time that it has been present. In general, then, a better result would be expected in a patient operated upon early in the course of his mitral heart disease (with *inactive* rheumatic fever) than in a patient who has had obstructive symptoms with possibly repeated bouts of congestive failure over a long time. A heart with multivalvular involvement and extensive myocardial damage would not be expected to re-

spond to commissurotomy as well as one in which the disease is mainly limited to the mitral valve. Lungs which have been severely damaged with arteriolar sclerotic changes in the pulmonary vessels due to the hypertension will not revert to normal, even though the obstruction at the mitral valve has been completely relieved. Furthermore, the liver and kidneys which have been severely damaged by repeated bouts of congestive failure lessen the chances of a good result. A rheumatic mitral valve will vary a great deal in the degree of thickening, stenosis, calcification, and involvement of the chorda tendinae and papillary muscles. These factors will determine the size and type of the opening that will be achieved by operation. In general, a mitral valve which is fibrous, relatively thin, and flexible, with no shortening of the chorda tendinae, will be a better functioning valve after commissurotomy than one which is very thick, calcified, stiffened, and has shortening of the chorda tendinae and fused papillary muscles. Occasionally, a valve will be encountered which has a normal opening, but with extensive fusion of the chorda tendinae and papillary muscles, producing a functional stenosis, described by Bailey as a subvalvular stenosis. Nothing can be done surgically with this type of valve and fortunately the condition is rare. Finally, clot, either fresh or organized, in the auricular appendage and/or left auricle does not influence the ultimate functional results, but does create the greatest hazard to the operation, and makes accessibility to the mitral valve more difficult. Such a situation may be expected in about 20 per cent of the patients.

Selection of Patients. The choice of patients for surgery is based on symptomatology, physical findings, and in some cases the catheterization findings. The latter test, however, is not usually necessary to arrive at a satisfactory diagnosis. A careful history and cardiac study, including electrocardiogram, fluoroscopic and x-ray examination of the heart, with postero-anterior and right and left oblique projections, will usually determine which patients are suitable for surgery. Catheterization studies are usually reserved for those patients in whom there is a question of the presence and degree of pulmonary hypertension, or in which there exists the possibility of some concomitant lesion such as an interauricular or interventricular septal defect, tricuspid insufficiency or transposed pulmonary veins. At the present time, it is not accepted policy to subject those patients to surgery who are asymptomatic. On the other hand, we do not believe that commissurotomy offers sufficient relief to patients who are in the terminal phase of their disease with irreversible congestive heart failure In general, the patients do best who have symptoms of pulmonary hypertension but who can be controlled by strict medical regimen Less favorable is that group who have progression of symptoms not responding well to strict medical regimen. The ideal patient is one who satisfies the following criteria:

1. The ideal age lies between 25 and 45 years Beyond the age of 45 the development of degenerative processes in the heart, such as arteriosclerosis and coronary artery disease, is a definite possibility, whereas in patients younger than 25 years, it has been our experience that reactivation of rheumatic fever following commissurotomy is more likely to occur.

2. Symptoms of pulmonary hypertension have been present for not more than two years and can be controlled on medical management.

3. The mitral valve is the only valve area involved by the rheumatic fever process and there is no element of insufficiency.

4. There is evidence by fluoroscopy and roentgenogram of a beginning enlargement of the left auricle and right ventricle.

5. There is a normal electrocardiographic pattern, or beginning right ventricular strain, and there is no sign of left axis deviation.

It is true that patients who do not satisfy the above criteria may be subjected to surgery and show improvement. However, the maximum improvement is generally not obtained. The presence of auricular fibrillation does not influence the choice of patients for surgery; however, it has been our experience that those patients who are fibrillating prior to surgery continue to do so after surgery, and attempts at converting are to no avail. A history of previous arterial emboli is no contraindication to surgery, in fact, it may be considered a definite indication, for the source of the emboli in the auricular appendage may be removed even if a commissurotomy cannot be carried out on the mitral valve.

The following are considered definite contraindications to surgery:

1. Active rheumatic fever or rheumatic carditis. This may be determined by symptomatology, physical and laboratory findings, including a sedimentation rate and antistreptolysin titer. If the activity of the infection can be controlled, then surgery may be done.

2. Chronic, irreversible heart failure. This implies severe damage not only to the heart, but also to the lungs, liver, and kidneys. Such patients may withstand the operative procedure, but no improvement may be expected.

3. Predominant mitral insufficiency. This may be difficult to determine. However, a loud systolic murmur over the mitral area associated with a very large left auricle and signs of left ventricular hypertrophy by electrocardiogram and x-ray examination is usually indicative of mitral insufficiency. Zinsser's angiocardiographic studies of the mitral valve(26) with opaque media may help to establish a diagnosis of insufficiency.

4. Subacute bacterial endocarditis. If the infection can be controlled, surgery might be considered.

SURGICAL MANAGEMENT

Preoperative Preparation. The patient must be brought to the optimum condition for his surgery under the meticulous supervision of the internist-cardiologist. It is essential that all evidence of congestive heart failure be eradicated. This may involve a prolonged period of bed rest along with a salt free diet and the intelligent use of diuretics. The cardiac rate must be controlled with the digitalis preparations; in fact, some patients who have never been in congestive failure may be placed on digitalis preoperatively, for it has been our experience that it usually prevents the occurrence of an extreme tachycardia or abnormal ventricular rhythms during the surgical manipulation of the heart. No attempt is made to convert fibrillation to a sinus rhythm preoperatively, but the fibrillation must be well controlled. The use of anticoagulants in patients who have had previous embolic phenomena has not prevented the occurrence of emboli during the opera-

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2. Symptoms of pulmonary hypertension have been present for not more than two years and can be controlled on medical management.

side elevated at approximately 45 degrees, as is advocated by some surgeons. The pericardium is incised over the left appendage (Fig. 5-2), usually posterior and parallel to the phrenic nerve, but may be incised anteriorly if the appendage is greatly enlarged. At this stage in the procedure, a local anesthetic drug, such as 4 per cent procaine or 2 per cent zylocaine, may be applied to the epicardium if the heart is found to be extremely irritable. Palpation of the left auricle will determine the presence or absence of a thrill indicative of regurgitation. Palpation of a thrill over the aortic valve is usually indicative of aortic valve disease. The presence of scarring and retraction of the auricular appendage may suggest the presence of an organized clot.

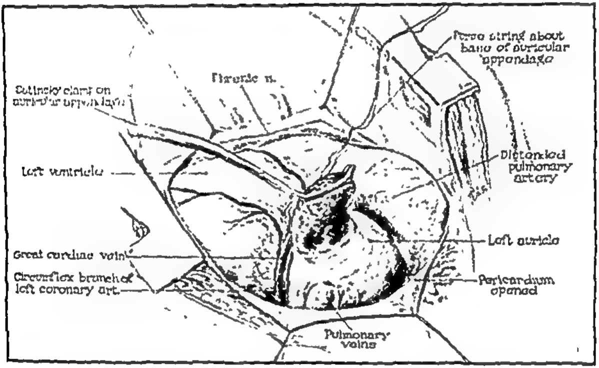

Fig. 5-2 View of heart after pericardium is opened. The purse-string suture has been placed about the base of the left auricular appendage. The very tip of the appendage has been clamped to facilitate placing of suture.

A purse-string suture, preferably of heavy silk, is placed about the base of the appendage (Fig. 5-2) and an opening made in the tip of the appendage. Vigorous bleeding from the appendage is allowed to wash out any fresh clots which may be present (Fig. 5-3). If no bleeding is encountered after opening the appendage, an organized thrombus probably exists and entrance into the left auricle can be established by creating a cleavage plane between the wall of the appendage and the fibrous capsule of the organized thrombus. Digital exploration of the left auricle and the mitral valve is then carried out to determine the presence of stenosis with or without regurgitation, and the possible existence of an interauricular septal defect. The size of the opening in the mitral valve and the condition of the chordae tendinae and the papillary muscles is determined (Fig. 5-4). With the patient in the lateral decubitus position, the anterior commissure will be directed toward the anterior axillary line, whereas the posterior commissure will be

tive procedure and for this reason its use is not recommended. Finally, it is desirable to have the patients admitted to the hospital approximately one week prior to surgery so that they may be accustomed to the hospital routine, have their apprehensions allayed by talking to other patients who have previously had the operation, and in general to place them in a receptive frame of mind for the operative procedure.

Anesthesia. Expert anesthesia given at the lightest plane possible commensurate with adequate surgery is essential to a successful commissurotomy with a minimum of complications. Patients with mitral stenosis tolerate heavy sedation and deep anesthesia very poorly; consequently, only enough preoperative sedation is given to allay apprehension and provide a dry tracheobronchial tree. Quickly dissipated drugs, such as nitrous oxide-ether combinations, are to be preferred, along with curare preparations to provide the amount of relaxation necessary. During the anesthesia, the promiscuous use of cardiac drugs to prevent or correct abnormal rhythms or hypotension are to be avoided except in the emergency when ventricular fibrillation or cardiac standstill occur. Instead, it has been found that interrupting the surgical manipulation and oxygenating the patients by lung inflation and lightening the plane of anesthesia will usually prevent or correct these complications.

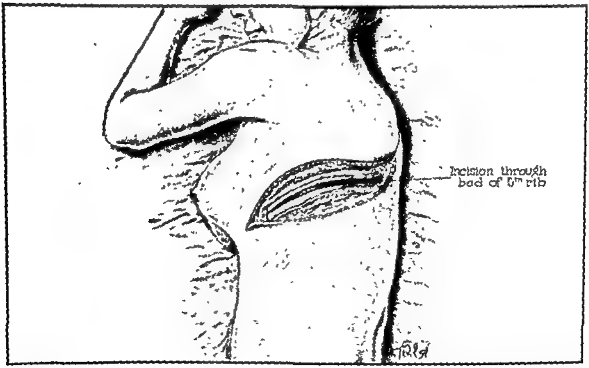

Fig 5-1. ... from anterior axillary line around tip of ... issimus dorsi and serratus anterior musc... mboid muscles posteriorly. The fifth rib has been resected subperiosteally

Surgical Technic. The patient is placed in the right lateral decubitus position and a *transthoracic incision made. A resection of the fifth rib is* preferred, although an intercostal incision through the fourth or fifth interspace may also be used (Fig. 5-1). This position makes the auricular appendage more available than the partially supine position with the left

directed toward the bodies of the vertebrae. After digital exploration the finger is introduced into the mitral orifice, and attempt at finger fracture by upward pressure on the anterior commissure is carried out. Counterpressure may be applied with the left hand over the left ventricle. If moderate pressure fails to tear the fused commissure, a knife is introduced along the right index finger and the commissure is engaged and cut. A variety of knives have been devised for this maneuver. If, after opening the anterior commissure, no regurgitation is produced, the posterior commissure is likewise finger fractured or cut (Fig. 5-5). When the fracturing of the anterior commissure produces a significant degree of regurgitation as evidenced by the jet stream on the palpating finger, then no further separation of the commissures is carried out, because increasing the opening will only increase

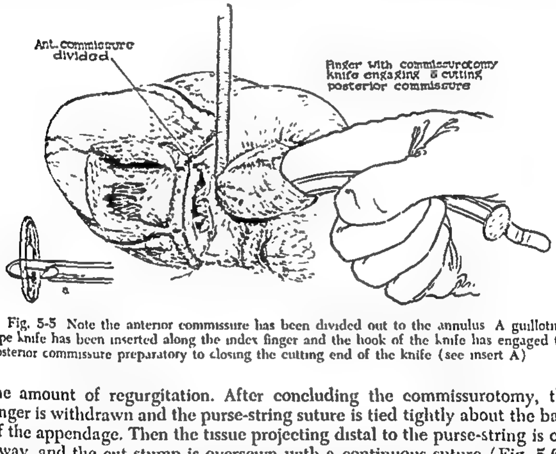

Fig. 5-5 Note the anterior commissure has been divided out to the annulus A guillotine-type knife has been inserted along the index finger and the hook of the knife has engaged the posterior commissure preparatory to closing the cutting end of the knife (see insert A)

the amount of regurgitation. After concluding the commissurotomy, the finger is withdrawn and the purse-string suture is tied tightly about the base of the appendage. Then the tissue projecting distal to the purse-string is cut away, and the cut stump is oversewn with a continuous suture (Fig. 5-6). The pericardium is then loosely approximated over the heart and after placing an intercostal tube for intrapleural drainage, a routine chest closure is carried out. During the operative procedure only enough blood is given to replace the estimated blood loss, and this rarely amounts to more than 500 ml. Throughout anesthesia and surgery a continuous electrocardiogram should be available so that signs of cardiac arrythmias due to anoxia or manipulative trauma may be detected and corrected before more serious complications occur.

Postoperative Management. Following a well executed operative procedure the postoperative course is usually benign, although the patient may complain of severe thoracic pain. It is frequently more intense than that from the usual thoractomy incision and may be difficult to control, even with the employment of intercostal nerve blocks or intercostal nerve resec-

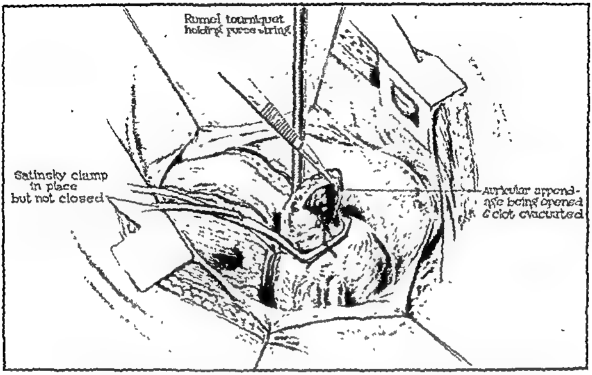

Fig 5-3 The ends of the purse-string suture have been fastened to the Rumel tourniquet and an opening made in the side of the appendage with a bayonet scalpel. Note the Satinsky clamp is not closed until a moment of vigorous bleeding is allowed. Depicted here is a fresh clot being washed away by the bleeding This is not the usual finding, but the presence of a clot in the auricle must always be kept in mind

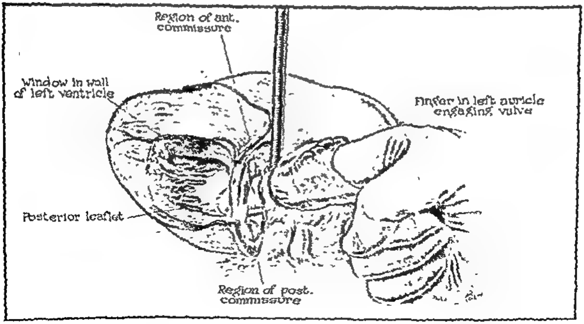

Fig 5-4. The right index finger is shown in the left auricle and engaging the mitral valve The purse-string suture is tightened around the finger to prevent bleeding The finger is left in the valve orifice only moments Note position of the anterior and posterior commissure when the patient is in the lateral position.

plication can be expected in about 10 to 15 per cent of the cases and will usually respond favorably to prolonged bed rests, salicylates, penicillin, ACTH-cortisone, or a combination of these drugs. The development of subacute bacterial endocarditis is a possible complication following any intracardiac manipulation, but fortunately its occurrence is rare.

Clinical and roentgenologic findings of an enlarged cardiac silhouette may indicate pericardial effusion or hemopericardium but these rarely occur if sufficiently large interspaces have been left between the sutures at the time of the closure of the pericardium. Tachycardia, dyspnea, and cyanosis may be relieved immediately by pericardial needle aspiration if done before the clot organizes.

Finally, there are the complications of any open chest operation, namely, atelectasis, pneumonitis, pneumothorax, hemothorax, pleural effusion, and empyema.

Results. The effects of the operation are evaluated on the basis of symptomatology, physical findings, and catheterization studies. In general, it may be stated that the degree of improvement as demonstrated by the changes in physical signs and catheterization studies do not always correlate with the apparent symptomatic improvement. This suggests that there may be a psychologic factor since a definite proportion of the patients with marked symptomatic improvement have revealed little improvement in the hemodynamics postoperatively as reflected in the catheterization studies. Furthermore, many of the patients catheterized repeatedly after operation have shown progressive improvement from an hemodynamic aspect up to 18 months following their surgery. Approximately 70 per cent of the patients will have symptomatic improvement, and of this group approximately 30 per cent will have no restriction whatsoever and will be able to discontinue digitalis, drugs, and salt restriction, and be unlimited in their physical activities. The remaining 40 per cent, although improved, still require some form of cardiac regimen. About a half of the 30 per cent who show no improvement will in fact be made worse by the operative procedure. In those patients having the most improvement, the diastolic murmur at the mitral area will be markedly diminished or even absent. A systolic murmur may be present but is usually of mild intensity. A small percentage of patients may show a definite decrease in cardiac size, radiographically, but this is an unusual finding. Oscillometric studies may demonstrate an increase in peripheral blood flow. Catheterization studies have revealed that the greatest fall in pulmonary artery pressure is usually in those patients who have the highest pressure prior to commissurotomy, and, conversely, the patients with the lowest pulmonary artery pressure preoperatively show the least fall postoperatively. More indicative of improvement by catheterization studies is the increase in the cardiac output, even though there seems to be no change in the pulmonary artery pressure. In those patients showing no improvement the usual cause is the development of an overwhelming mitral insufficiency. At the present time, a mortality of 5 or 6 per cent may be expected due to the causes listed above. Since the surgeon is unable to anticipate the occurrence of arterial emboli, the mortality rate will probably remain at this level.

tion. Changes in cardiac rate or rhythm must be anticipated and corrected promptly if they occur. The persistence of tachycardia may indicate the need for increasing the digitalis therapy. Auricular fibrillation occurring on the third or fourth day postoperatively is not an unusual complication and early conversion to sinus rhythm is usually desirable. However, some cardiologists prefer to wait six weeks to two months before attempting conversion to normal rhythm. In patients with a low pulmonary reserve due usually to pulmonary fibrosis, the use of the intermittent positive pressure breathing apparatus may be necessary to afford adequate oxygenation. Except for the above, the management is usually that of any thoracotomy patient with attention to maintaining a dry tracheobronchial tree and preventing the development of any severe pulmonary complications.

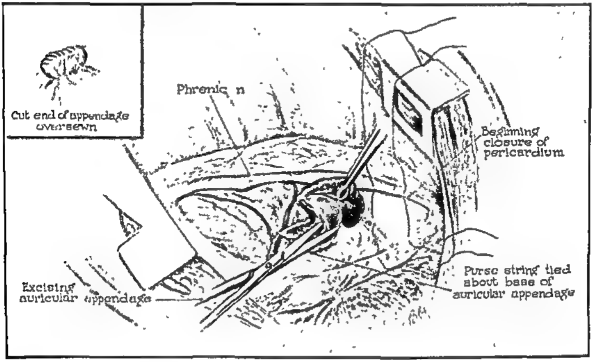

Fig 5-6. The finger has been withdrawn and the purse-string suture tightened about the base of the appendage The redundant portion of the appendage is now cut away. The open end is then oversewn to complete the closure Two to three sutures is all that is required to approximate pericardium that is allowed to drain into the pleural space

Postoperative Complications. Arterial emboli are the most serious complication following commissurotomy. They may occur in any part of the arterial tree, but most commonly the brain and lower extremities are involved. This catastrophe occurs during or soon after operation and can be detected at the time of occurrence or soon afterward. The incidence of emboli is about 5 per cent and accounts for the greatest mortality. Congestive heart failure is the most common complication. It is usually due to the creation of a predominant mitral insufficiency, a markedly diseased myocardium, or both. Some patients will have persistently elevated temperatures in the period, along with leukocytosis, a markedly increased sedimentation rate, and pleural-pericardial and joint pain These findings have been interpreted to be indicative of a reactivation of the rheumatic fever state. This com-

tricular enlargement should have the benefit of surgery. The contraindications to surgery are: 1, uncontrollable congestive failure; 2, signs of severe myocardial deterioration as evidenced by extreme left ventricular enlargement and gallop rhythm; 3, evidence of rheumatic fever activity; 4, subacute bacterial endocarditis; 5, advanced age. The serious complications are: 1, ventricular fibrillation; 2, cerebral emboli; 3, creation of an aortic insufficiency; and 4, hemorrhage from the left ventricle.

A longer follow-up on operated cases will be necessary before aortic commissurotomy can be truly evaluated.

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OTHER VALVE LESIONS

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The attempts at surgery have been aimed at decreasing the size of the valve orifice during ventricular systole. Harken has devised a plastic "baffle bottle" which is placed below the mural leaflet with the neck of the bottle engaged beneath the edge of the aortic leaflet. Experimentally, there is evidence to show that this procedure may have some merit(11). Bailey at first tried a pedicled transventricular pericardial graft which floated upward at the end of diastole and occluded the mitral orifice(7). This procedure was abandoned because of the high operative mortality and because the pericardial graft was found to ultimately shrink and disintegrate. He then tried mitral suturing whereby a piece of pericardium is sutured into the edges of the valve leaflets thereby decreasing the mitral orifice(7). In general, these technics have not been accepted due to the high mortality and uncertain results, but certainly their efforts represent a great pioneering effort.

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galy is also a common occurrence in portal hypertension intrahepatic in origin.

Another type of extrahepatic portal obstruction is generally seen near the entrance of the vein into the liver and as a rule occurs in infants or early childhood. This may consist of either a fibrous replacement of an obliterative type or in a cavernous transformation. Both of these types have been recently stressed by Whipple(1).

When the obstruction is within the liver and the pressure within the portal system is elevated, a relatively increasing amount of blood must enter the liver through the hepatic artery. This generally is accomplished by the formation of so-called collateral circulation. In such a manner portal blood is partially shunted into the general circulation and thus eventually enters the liver through its arterial supply. There are two groups of veins which play an important part in this collateral circulation. In one group fall the accessory veins of Sappey, which are the veins which enter the liver directly without passing through the portal vein. While these are small structures, in disease they may become quite large. They are the veins seen in the supporting ligaments of the liver, namely, the suspensory ligament, the gastrohepatic omentum, the veins between the gallbladder and the liver, and the hepatocolic and hepatorenal veins. The other groups of veins involved in the collateral circulation are numerous, but the chief groups are those anastomosing with the coronary vein, the middle hemorrhoidal, and the para-umbilical veins.

The importance of this collateral circulation to the surgeon lies in the fact that the collaterals of the coronary especially may become huge, sometimes 1 cm. or more in diameter. As they extend up the lesser curvature of the stomach and invade the wall of the stomach and esophagus they tend to form huge submucosal sinuses that extend up the esophagus in a longitudinal direction. Interestingly enough, these submucosal plexuses are usually not very prominent in the antrum of the stomach and that portion of the gastrointestinal tract lying distal. Erosions are frequent and massive hemorrhage occurs These hemorrhages may be exsanguinating in amount and often are fatal. In reported studies such hemorrhage is the immediate cause of death in as high as 30 per cent of the patients who die from cirrhosis of the liver Therefore, the patient who has had a single such hemorrhage and survives, lives in constant terror of others.

Besides the clinical picture of congestive splenomegaly and recurrent attacks of hemorrhage, the patient with portal hypertension frequently is embarrassed by a third finding, namely, the appearance of ascites. At the present time there is some question as to whether or not ascites as seen in portal hypertension is due entirely to increased intrahepatic resistance. Other factors seem to be involved, perhaps related to protein synthesis and hormonal influence. The effect of the lowering of the portal hypertension on ascites, however, is at times dramatic; and it, therefore, should be considered along with congestive splenomegaly and hematemesis as one of the indications for surgery.

The surgical approach to the relief of portal hypertension historically has followed one of two general principles. The first is the establishment of a fistulous connection between the portal and general circulation, and the

6

THE SURGERY OF PORTAL HYPERTENSION

NATHAN A. WOMACK

Portal hypertension may result from obstruction of the portal vein or some of its branches, before they reach the liver, within the liver or in the hepatic vein or vena cava. The last two sites are so unusual and lend themselves so poorly to surgical attack that they might well be ignored in this discussion.

Physiologic Considerations of Portal Hypertension. Ordinarily in the portal vein the pressure is low, ranging from 6 to 12 mm. of mercury (8 to 16 cm. of water) in the normal human, although in disease this often is elevated three or four times as high. Since the pressure in the hepatic vein is close to that of atmospheric level, liver capillary pressure is extremely low and blood flow in the portal system is slow. However, the pressure in the portal system within the liver probably is modified considerably by the influence of the hepatic artery. Hepatic artery blood probably merges with portal vein blood before these vessels reach the sinusoids of the liver. The volume of blood entering the liver through the hepatic artery under normal conditions has been variously estimated but probably is approximately 25 per cent. This in itself would serve as one factor modifying the pressure level in the portal system, and this effect would vary with systemic arterial pressure. In cirrhosis this effect is markedly exaggerated. Many other factors come into play to make the regulation of portal pressures extremely complicated. Among these are the action of the splanchnics, the possible presence of sphincter-like action at the junction of the hepatic veins and the vena cava, probably sphincters near the central veins within the liver, the sinusoids of the liver, and the intrahepatic tension as affected by parenchymal metabolism such as lipid infiltration or edema. The effects of intrahepatic obstruction are thus variable.

Obstructions outside of the liver are much more consistent. Most dramatic of these is occlusion of the splenic vein This is most often seen in that portion of the vein adjacent the pancreas and usually is secondary to trauma. This results in increased intrasplenic tension with gradual hypertrophy and hyperplasia of the reticulum as a result of congestive effects. Apparently the spleen takes on increased function insofar as its destructive capacity is concerned and the patient seen presents a picture of so-called hypersplenism. There usually is moderate to severe secondary anemia, decrease in blood platelets, and leukopenia The spleen is enlarged and firm. Often, due to the collateral circulation through the vasa brevia and the left gastroepiploic, there is a marked gastric congestion and the patient may have episodes of hematemesis. The clinical picture is a classic one, and the condition responds adequately to splenectomy Such congestive splenome-

portacaval anastomosis a satisfactory one. Neither is it necessary that the kidney be removed. The technic described by Gross is an adequate one (Fig. 6-1).

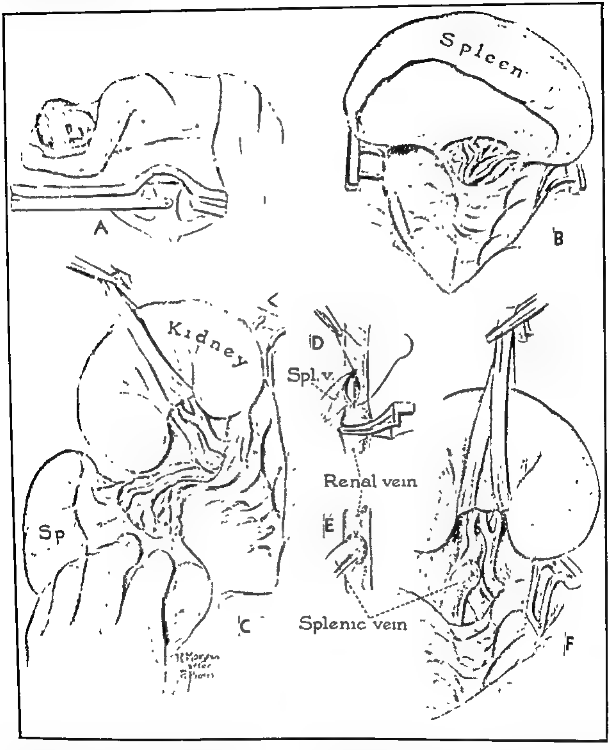

Fig 6-1 Technic for splenorenal shunt A, the patient is placed in a lateral position. B, spleen mobilized C, renal vessels isolated D, E, and F, the splenic vein is anastomosed to the renal vein (After Gross, R E, The Surgery of Infancy and Childhood. Courtesy W. B. Saunders Co)

Numerous technics have been described for the direct portacaval anastomosis. There is still disagreement, however, as to the relative effectiveness of the side-to-side anastomosis between the vena cava and the portal vein as compared to the end-to-side At the present time the latter procedure seems

latter has to do with lowering the portal tension by excision of viscera or portions of viscera within the portal system, thus reducing the amount of blood necessary in the portal vein.

The shunt between the portal and venous systems is the methods used by the body in overcoming intrahepatic occlusion of the portal vein. As this collateral circulation increases, the relative amount of blood supplied the liver by the hepatic artery increases; and it has been estimated that in some advanced states of cirrhosis approximately 85 per cent of the hepatic circulation is arterial. This effective arterial supply probably explains why some patients with a huge amount of scarring in the liver present no clinical evidence of hepatic dysfunction and suggests that probably functional decompensation occurs in advanced cirrhosis chiefly when the arterial branches become insufficient. In the light of such a functional consideration, the surgical performance of a shunt between the two circulations would seem to be less formidable physiologically; and this concept would seem to be verified experimentally(2). At the same time one must bear in mind the possible ill effects of the sudden removal of a large amount of portal circulation from the liver with possible episodes of intoxication. This will be particularly hazardous to proper protein metabolism.

The most classic of the older operations for the establishment of such a shunt is the Talma-Morrison procedure of omentopexy. Although this procedure has had its enthusiastic supporters in times past, the over-all picture has not been too satisfactory. While many patients have had a probable decrease in the amount of ascites for a variable period of time, the shunt has never been very effective in lowering portal hypertension. Modifications of this procedure such as excision of the parietal peritoneum along with omentopexy have had their supporters but this, too, has been effective chiefly in the partial relief of ascites but not in the other effects of portal hypertension.

While a direct approach in the performance of such a shunt has been known for many years following the work of Eck, it is due to the more recent aggressive attack through this method by Whipple, Blakemore(3), and others that the performance has been applied clinically.

The first procedure tried by them in a considerable number of cases was an anastomosis between the splenic and renal veins after removal of the spleen and the left kidney. Several technics have been developed by them and others for the performance of this anastomosis which are described in detail in several reports. In the few years which have elapsed since the utilization of this type of shunt, there have been a considerable number of dramatic results described in the literature. However, as results have been evaluated with the passage of time, at the present writing it is becoming more and more evident that this procedure is unsatisfactory in many instances. Its technical performance is often difficult and even impossible in those patients who have had previous splenectomy. Leaks, thrombosis and stenosis of the anastomotic site probably have made this a less desired procedure to that of the direct portacaval shunt.

It still remains probably the best procedure to use in children where the obstruction is extrahepatic and in the region of the porta. In such instances there is usually no single, large portal vein that would make a direct

and gallbladder are pushed forward by gentle dissection, the portal vein and vena cava isolated at that site where they run parallel and in juxtaposition. Because of the danger of long occlusion of the vena cava, continuity of circulation is maintained by the use of a modified clamp after the type used by Potts in operations upon the thoracic aorta. The circulation in the portal vein is occluded by bulldog clamps above and below the site of anastomosis (Fig. 6-2). A single row of continuous mattress sutures of fine silk is used producing an intima-to-intima contact after the method of Blalock in his operation for pulmonic stenosis. As soon as the anastomosis is established, the clamps are removed from the portal vein, and then from the vena cava. Thrombosis is rare, due to the fairly rapid circulation of the vena cava. There is an immediate adjustment of pressures so that the pressure in the portal vein becomes almost identical to that in the vena cava, as can be measured by manometers placed in radicles of the portal vein before closure of the abdomen.

In performing the end-to-side anastomosis between the portal vein and the vena cava, the technic described by Welch is a satisfactory one. The same approach as that given in the side-to-side anastomosis may be used. The portal vein is sectioned as near the liver as is feasible and anastomosed to the anteromesial surface of the vena cava (Fig. 6-3).

Although these procedures have at the present writing been performed in a fairly large number of patients and the time during which they have been observed relatively short, it probably represents the best direct approach to the problem of lowering the blood pressure in the portal system. The effect of such a portal shunt on the nutrition of a damaged liver has yet to be determined. Statements as to its benignancy are as of now to a considerable extent speculative.

Splenectomy for Portal Hypertension. The second general approach toward the lowering of portal tension, as mentioned above, has had to do with the excision of viscera which drain into the portal vein. The most classic of these is that of splenectomy. It has been estimated by some that approximately 40 per cent of the blood going to the portal vein has its origin from the spleen; and it, therefore, would seem that excision of the spleen would offer considerable relief in the symptoms resulting from portal hypertension as well as those from congestive splenomegaly. For a number of years now splenectomy has been performed particularly in those patients in whom the symptoms of congestive splenomegaly have been dominant and in whom functional liver damage has been minimal. By and large, the results have been good for only a relatively short length of time. The effect of splenectomy on esophageal varices and ascites has been most disappointing. While the use of this procedure is dramatic when the hypertension is limited to the splenic vein, used elsewhere its limitations are so great as to raise some question as to the advisability of its use as a sole procedure.

Gastrectomy and Resection of Distal End of Esophagus for Portal Hypertension. Recently Phemister and Humphreys(4) reported two instances of a more aggressive approach in such visceral excision. One consisted of a total gastric resection and the other of resection of the lower esophagus and upper stomach. The immediate results in both of these patients were good. Both

to be gaining in favor. A satisfactory technic for the former is that established by Blakemore (Fig. 6-2).

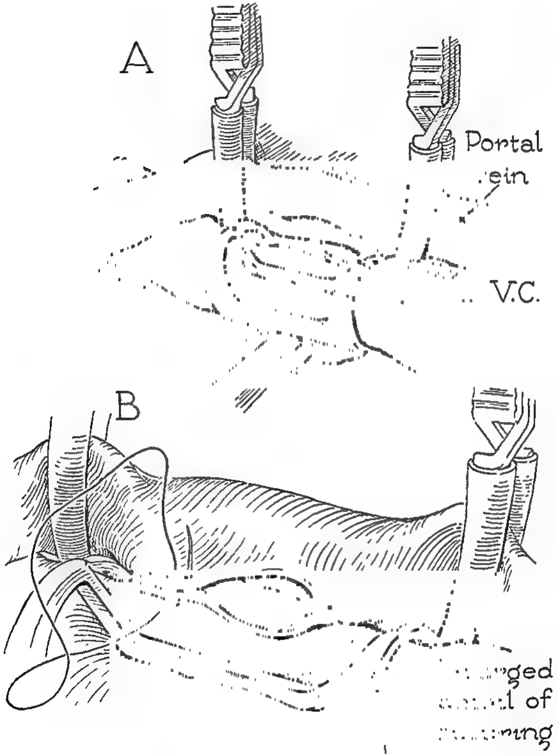

Fig. 6-2. Side-to-side portacaval anastomosis utilizing the principles advocated by Blakemore.

Technic of Portacaval Shunt. The portal vein and vena cava are best approached with a posterolateral incision by subperiosteal excision of the right ninth rib, although a lower incision may be utilized. The anterior approach is much more difficult technically. The duodenum, common bile duct,

domen is opened by a radial incision through the diaphragm with or without previous paralysis of the left phrenic nerve. Because of the large number of fragile veins, it is wise first to approach the spleen from behind. The splenic artery is ligated proximal to the origin of the vasa brevia and the left gastro-epiploic. This artery often is as much as twice its normal diameter, and double ligation is advisable The left gastroepiploic artery and vein are ligated at a point about opposite the level of the origin of the left gastric artery. If there is evidence of varicosities involving the entire stomach wall, more stomach may be removed. The splenic vein is doubly ligated and the

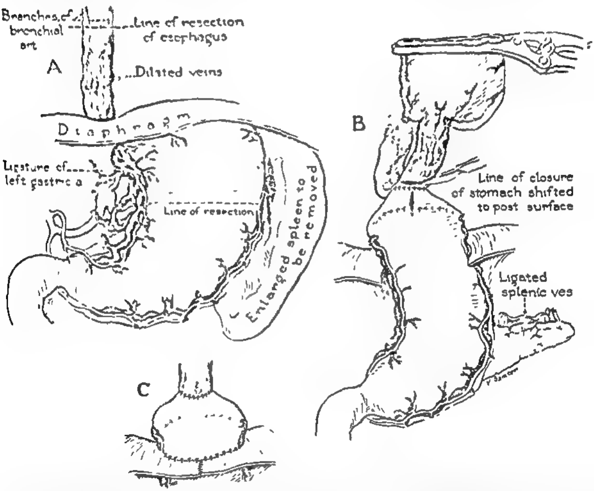

Fig. 6-4. Resection of upper half of stomach and distal end of esophagus for hemorrhage from esophageal varices A, after exposure through a combined thoracoabdominal incision the left gastric artery and vein are ligated and the stomach transected at its midportion B, after removal of the spleen the esophagus is anastomosed to the stomach. C, after completion of the anastomosis the diaphragm is anchored to the stump of the stomach to prevent herniation.

spleen removed. By gentle dissection the left gastric artery is brought into view just beyond its origin from the celiac and doubly ligated. The mediastinal pleura is now reflected off from the esophagus about 10 cm. above the diaphragm at the level of rich blood supply to the esophagus from branches of the bronchial artery The large veins which exist behind and to the right of the esophagus are then doubly ligated. The coronary vein is then ligated just before it enters the portal. It then is possible to excise dilated veins, when present, along the course of the coronary without a considerable loss of blood. The stomach is sectioned at the midportion of the body

operations were performed for massive hemorrhage from esophageal varices, and subsequent hemorrhage was completely alleviated in both instances.

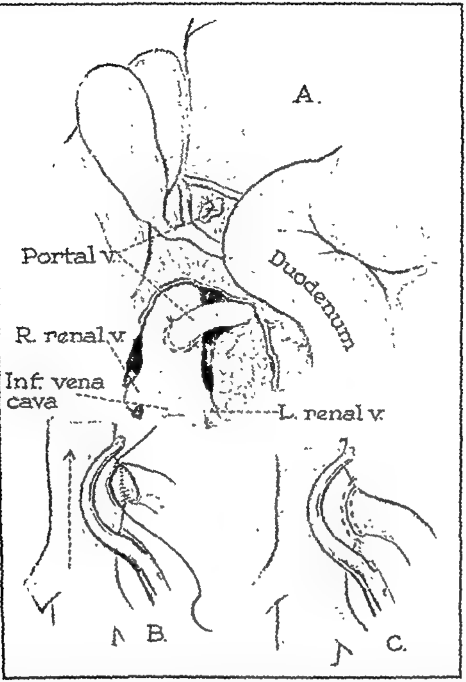

Fig. 6-3 End-to-side portacaval anastomosis A, completed suture B, anastomosis of the end of the portal vein to the side of the vena cava above the renal vein entrance with the Thomas Smith clamp in place, using a continuous suture of fine silk Note forced caval flow beneath the clamp C, anastomosis completed. Note everted type of suture. (After Welch, C. S. Surg, Gynec & Obst, 85:492, 1947)

Recently, we have modified the procedure of Phemister and Humphreys slightly to include the lower portion of the esophagus, the upper half of the stomach, and the spleen. The technic which we have used is illustrated in Figure 6-4.

The left eighth rib is removed subperiosteally with an incision carried from the angle to the costal cartilage. The suspensory ligament of the lower lobe of the left lung is sectioned and the lung reflected upward. The ab-

Attempts to relieve ascites by the insertion of glass buttons have been at the best of only temporary value in establishing such relief, and we doubt seriously their indication.

The underlying pathologic disease producing intrahepatic origin of portal hypertension always is of a serious nature. The most common cause is that of fibrosis of a progressive sort which may have its origin from several underlying causes. This picture of cirrhosis of the liver is, at the present writing, a most confused one. As new light is being shed upon the subject, the historic classifications of the disease seem no longer to hold. Because a detailed discussion of the disease would be most involved, it cannot be considered here. Suffice it to say, in every instance where the condition has progressed to the extent that there is a marked increase in portal pressures, liver function is considerably altered. Oftentimes the intensity of liver damage cannot be ascertained by the common laboratory tests of liver function. The liver function may be compensated adequately in the face of severe disease and yet decompensate within a very short interval. We have on numerous occasions encountered situations in which extensive cirrhosis of the liver was present but all functional tests within normal limits. It is assumed that in these instances the hepatic arterial circulation has been the compensating mechanism. As yet, one has no way of knowing when this compensating circulation, however, will become embarrassed. We have come to feel more and more insecure by relying on so many of the present functional tests. There are two such estimations, however, which seem to be of considerable value. The most important of these is the ability of the liver to synthesize albumin. When the level of albumin in the blood is markedly diminished, surgery of any sort becomes exceedingly hazardous. Another test that has proven to be of clinical value has been the ability of the liver to excrete bromsulfalein from the blood stream. Where the liver damage is great enough to have a level of bromsulfalein of as much as 40 per cent left in the blood stream 30 minutes after injection, we are loath to advocate extensive surgery of any sort.

It must be understood that both the portacaval shunt and the massive resection of esophageal and gastric tissue and the spleen are at the present time hazardous procedures. They should never be undertaken lightly. Perhaps the best indication for either of them is impending death from massive hemorrhage from esophageal varices Where this situation coexists in a patient with compensated liver function, the indication for such surgery is greatest. Which of the particular procedures is preferable, it is impossible to state at the present writing. It is well to consider the habitus of the patient, the technical skill of the surgeon, and many other individual factors.

The evaluation of the effectiveness of an operation for bleeding esophageal varices is difficult indeed. The patient is generally a desperate surgical risk. Again many internists will note an episode or two of massive hemorrhage in such patients and find that spontaneous recovery apparently takes place to the extent of no further bleeding for periods as long as five years, even though varices may be demonstrated roentgenologically.

It also is well to remember that the surgery of portal hypertension, as described above, may influence the preservation of liver function but little. Progressive decompensation of liver function, therefore, often continues;

and the mucosa closed with a running suture of very fine catgut. This is best done without clamps on the lower segment in order to visualize properly the presence of intragastric varicosities which might be left behind. If such varicosities are seen, the stomach necessarily will have to be resected at a lower site. Serosa is brought to serosa on the stomach by interrupted mattress sutures of fine silk. The upper portion of the stomach and the lower esophagus are gently lifted from their beds and a row of interrupted sutures of fine silk placed transversely between the esophagus and stomach well in front of the previous gastric suture line. A longitudinal incision then is made in the stomach and an inner row of sutures placed between the esophagus and stomach with fine mattress silk. The esophagus then is transected and the outer row of fine silk sutures continued. The stomach is brought well up into the mediastinum in order that there be no tension and the diaphragm closed. The stomach wall is sutured to the diaphragm in order to prevent subsequent herniation. The lung is expanded, the thoracic incision closed with interrupted silk, and a Foley catheter inserted through a small (air tight) intercostal incision and the catheter connected to a small flask of water and all pneumothorax relieved. This tube generally is withdrawn within 24 to 48 hours.

Because it is necessary to sacrifice both vagus nerves, it is generally advisable to section the pyloric musculature. This is adequately and quickly done with a 4 cm. longitudinal incision that is closed transversely. We prefer not to leave an indwelling catheter in the stomach because of its potential damaging effect on the anastomotic suture line. When peristalsis can be elicited, the patient is started on liquids by mouth. This is usually within 48 hours of operation.

We have not been able, as yet, to observe a considerable group of patients in which this procedure has been performed for a long enough time to express a final opinion. Where the operation is performed properly and all varicosities removed, subsequent gastric hemorrhage is alleviated. Obviously, the effects of congestive splenomegaly also are done away with. We have been pleased to observe the disappearance of ascites in every instance in which it has been present. All of the patients have been able to resume their work and have gained weight. Because of the importance of nutrition in cirrhosis of the liver, this has been most satisfying.

Discussion of Relative Values of Various Operative Procedures. Rienhoff(5) has recently advocated the ligation of the hepatic artery just distal to the origin of the gastroduodenal artery along with ligation of the splenic artery as a method of controlling hemorrhage from bleeding esophageal varices. This operation must await critical evaluation In the hands of others the results have not been too successful

Less drastic approaches to the relief of gastric and esophageal hemorrhage from varicose veins by ligation of the veins or injection with sclerosing substances, in our experience, have been futile At the same time transesophageal ligation of varices may be a lifesaving measure when the bleeding cannot be controlled by balloon tamponade and the patient is too ill to stand a more formidable surgical procedure An excellent technic for such a ligation has been described by Crile, who has advocated it for definitive treatment of this condition when due to extrahepatic obstruction(6).

7

THORACIC WALL, PLEURAL CAVITY, LUNGS, AND DIAPHRAGMATIC HERNIA

John M. Dorsey

THORACENTESIS

One of the simplest procedures which the surgeon is called upon to perform in the thorax is the introduction of a needle through the chest wall for purposes of diagnosis or therapy. Yet it is a most fundamental operation and if it is to be properly carried out so as to obtain the greatest information and success with the least risk of danger, it must be undertaken with a complete knowledge of the anatomy of the thoracic cage, its coverings, its contents, the physiology of its function, the pathologic processes which involve it and the roentgenologic signs with which any of the above are associated.

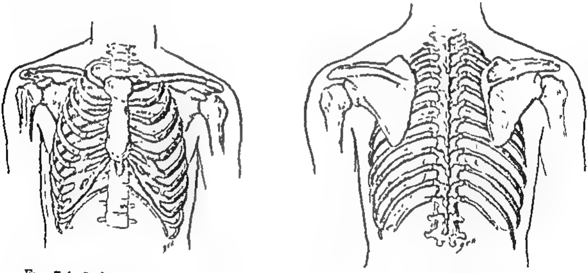

Fig. 7-1. Left, anterior view of the bony thorax. Right, posterior view of the bony thorax.

Anatomic Considerations. Roughly, the thorax resembles a truncated cone. The smaller base superiorly is the thoracic inlet. The larger base below is comprised of the diaphragm. If we bare the bony framework of its coverings and remove its contents, it appears as in Figure 7-1. The spongy and very vascular sternum is made up of three segments. Extending downward from the suprasternal notch is first the manubrium which is the thickest segment. Its superior margin is in the same horizontal plane as the inferior border of the second thoracic vertebra, the distance separating them being about 5 cm. or the anteroposterior dimension of the thoracic inlet. The manubrium joins with the thinner body (gladiolus) to form an important surface landmark, the angle of Ludwig, which lies on the same plane as the

thus, the main value of the surgical procedure is that of maintaining freedom from massive hemorrhage over a period of time. At its best then, it is surgery of desperation. Eventually the best treatment of portal hypertension will be its prevention.

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forward next between the layers of the internal intercostals and in front, on the inner side of the latter.

To further cover the thoracic cage (Fig. 7-3), we find that the extrinsic muscles on the anterior and lateral aspects are innermost, the pectoralis minor, arising from the anterior surfaces of ribs two to five, inserting into a tendinous attachment to the coracoid process of the scapula. More lateralward and posteriorly, forming the medial border of the axilla, the digitations of the serratus anterior arise from eight to nine of the uppermost ribs to insert into the angle and vertebral margin of the scapula.

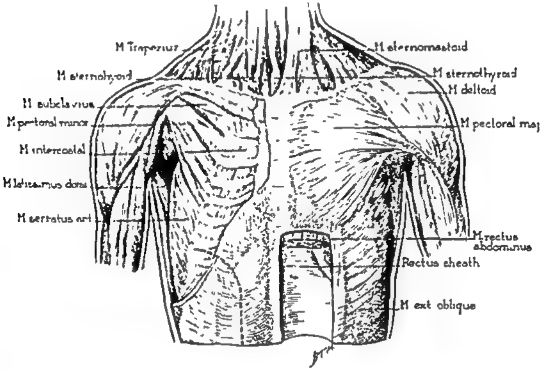

Fig 7-3 Muscles of the anterior thoracic wall The location of these is most important in planning of incisions, as used for example in the abdominothoracic exposures, the incision for which is illustrated by the dotted line on the patient's right.

Covering these muscles anteriorly is the pectoralis major, arising from the medial half of the clavicle, the anterior surface of the sternum, and of the second to seventh costal cartilages, and the anterior leaf of the sheath of the rectus abdominis. These fibers converge to insert lateral to the major crest of the humerus. Figure 7-4 shows(6) the other thoracic wall muscular coverings, including those of the shoulder girdle, and their relation to the folds and surface markings of the overlying integument. Not illustrated are the major and minor rhomboid underlying the trapezius, and the sacrospinalis group occupying the trough between the vertebral column and the rib angles. All of these stand in direct relationship to the periscapular incisions so frequently used in thoracotomies.

There is an abundant vascular supply to the chest wall, the principal vessels of which are the internal mammary and intercostal arteries. The first two or three pairs of the latter arise from the superior intercostal branch of the costocervical trunk which, in turn, is a branch of the second portion of the subclavian artery (that part median and dorsal to the anterior

body of the fifth dorsal vertebra and marks anteriorly the point of articulation of the second costal cartilage with the sternum. The union of the body of the sternum with the xiphoid (ensiform) process corresponds in level posteriorly with the cartilage between the ninth and tenth thoracic vertebrae.

Upon the bared bony thorax can best be projected the conventional longitudinal lines related to the enclosed viscera. The midsternal line bisects the sternum and corresponds to the line of the midback; the midclavicular (mammary) line dropped from the midpoint of the clavicle passes ordinarily medial to the nipple; the parasternal line lies midway between the midclavicular and midsternal lines. The anterior, posterior and midaxillary lines are dropped from the anterior and posterior axillary folds and from the middle of the axillary space, while the scapular line runs through the apex of the inferior angle of the scapula.

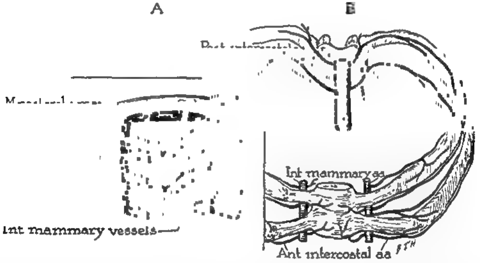

Fig 7-2 The relation of the internal mammary and intercostal arteries to the ribs and chest wall A, the internal mammary vessels lie on the pleura about 1 25 cm lateral from the sternum The anterior intercostal branches are given off near the center of the corresponding intercostal space B, the posterior intercostal vessels arise from the thoracic aorta, and are protected in the intercostal groove of the corresponding rib

Reconstructing the chest wall anatomically to emphasize the surgically important points, one should first add to the bony cage the internal intercostal muscles, which are expiratory, in function. As their name implies, they are internal and arise from the inferior margin of each rib forward from the angle, almost to the margin of the costal cartilage, running in a direction downward and vertebralward to the upper margin of the next rib below. External to these, contributing to the covering of the intercostal spaces are the external intercostals which are muscles of inspiration. They arise from the lower margin of each rib from the tubercles forward to the lateral end of the costal cartilage, running downward and sternalward to the margin of the next rib below. This point is to be emphasized so that the surgeon may understand the rationale of the maneuvers in rib resection as described in Figure 7-13.

Figure 7-2 shows the relationship of the intercostal arteries (and therefore all of the intercostal vessels) to the ribs and intercostal spaces. Behind they lie between the external and internal intercostal muscles, as they run

the pleural space is brought into contact with the outside atmospheric pressure unless such a needle is attached to an airtight syringe. If this is small enough and the plunger moves readily and there are a few cubic centimeters of air in the chamber, the plunger will move with the respiratory rhythm, inward with inspiration and outward with expiration.

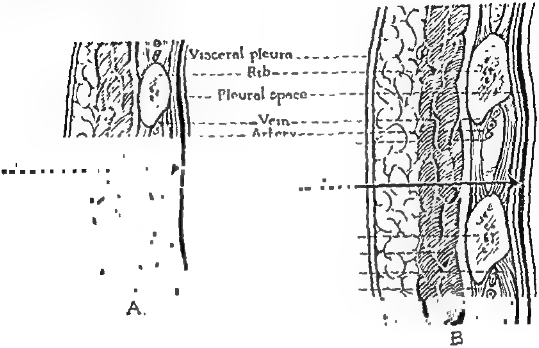

Fig 7-5 A, vertical section through the ribs and interspaces anterior to the axilla. A needle or trocar must be inserted in the center of the interspace to avoid injury to intercostal vessels which are unprotected by rib or costal cartilage. B, posterior to axilla. The intercostal vessels and nerve lie protected in the intercostal groove They are avoided most safely by an approach immediately above the rib

Inflammatory fluid accumulates in the chest according to the laws of capillary attraction. Its conformation is affected also by the elasticity of the pulmonary tissue, that is, the more air-containing compressible portions of the lung allow for fluid accumulation, whereas the more resistant hilar portions do not. This fluid may be serous, serohemorrhagic or bloody in character. Such fluid may become purulent. If, during the course of its formation, communication with atmospheric pressure either by means of a bronchopleural fistula or puncture of the chest wall occurs, a fluid level develops; that is fluid overlain by air. Such fluid levels are also present in accumulations within the lung, as in lung abscess wherein a bronchus allows for the entrance of air and evacuation of some of the accumulated pus.

Serous fluid may be aspirated for diagnostic purposes, that is, culture, direct smear, guinea pig inoculations and cell block study, with small bore needles, preferably 18 to 20 gauge. Thicker fluids, such as purulent pneumococcic pus or blood, require larger needles of the 13 to 16 gauge size. These may be introduced through the chest wall, attached to a 5 ml. syringe after adequate novocain anesthesia has been effected. If the fluid is in large quantities, and has caused the underlying lung to be compressed away from the chest wall, then sharp long beveled needles may be used with impunity. However, if there exists only a thin layer of fluid then short beveled needles should be used This is to prevent injury to the underlying

scalene muscle). The inferior nine pairs arise directly from the aorta. The internal mammary arteries are given off from the first portion of the subclavian and pass inferiorly, anteriorly and mesially on the pleura. They lie behind the sternal end of the clavicle on each side and descend into the chest along the lateral margin of the sternum, parallel to and about 1.25 cm. from it At the level of the sixth intercostal space they divide into lateral musculophrenic and medial, terminal, superior epigastric branches.

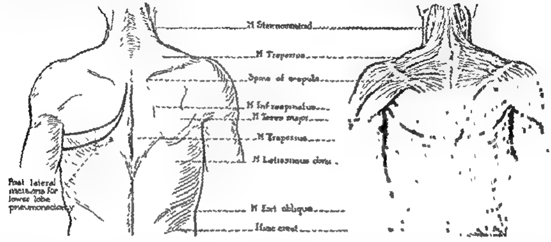

Fig 7-4 The relation of surface anatomy to the musculature of the back. The upper incision for pneumonectomy is designed to allow for resection of the fifth or sixth rib The lower incision for lower lobe lobectomy the sixth or seventh rib Both of these are made with the scapula pulled forward with the patient in the lateral recumbent position As is mentioned in the text, these are periscapular incisions and should *curve below* the angle of the scapula, and not across it.

All of these anatomic facts are essential knowledge in the performance of thoracentesis The needle must be introduced into the desired space so as to avoid injury to these structures. Figure 7-5 illustrates the difference in their location in relation to the ribs, depending on whether the chest is entered posterior to the axilla or anteriorly to it. Posteriorly, they lie protected in the intercostal groove and therefore the safest course for the needle should be close to the upper margin of the rib; while anteriorly, the vessels lie exposed in the interspace, so arranged that they may be best avoided by entering the middle of this region.

Physical and Physiologic Considerations. The selection of a needle for entering the pleural space brings into focus the necessity for a knowledge of the physiology as well as the anatomy and the pathologic anatomy of the thorax. It is the cohesive force between the visceral and parietal pleural layers measured in terms of negative intrathoracic pressure that maintains the lungs in an expanded state This is increased (made more negative) in inspiration when the lungs distend to completely fill the pleural space, and decreased in expiration. The elasticity of the lung tissue would cause the lungs to retract away from the chest wall if this cohesive force were not present. Ordinarily, this is measured in terms of centimeters of water and is, on an average, from -7 to -10 being greater, as has been stated, on inspiration. Only when the chest wall is intact does this condition exist A needle introduced through the chest wall disturbs this relationship unless some adhesive process has obliterated the pleural space. Through the needle bore

has been removed. This needle is advanced slowly, depositing about 5 ml. of novocain into the intercostal muscles and down to the pleura, where the last 2 to 3 ml. of solution are deposited. A few seconds should be allowed to elapse for adequate anesthesia to develop The needle is allowed to remain in place while the syringe is refilled and the needle selected for entering the pleural space. It is important here to emphasize the use of a small 5 ml. syringe in these steps. The tactile sensations relayed from the needle point are more easily felt with a small syringe than with the large 20, 30 or 50 ml. size.

Pitfalls and Precautions. 1. If insufficient local anesthesia is used pain may cause the patient to move, plunging the needle unexpectedly into the lung.

2. The patient should be cautioned to make every effort not to cough. Violent coughing will cause the lung to expand and impinge itself upon the needle.

3. Fluid should not be removed too rapidly or with too much pull on the plunger of the syringe. According to physical laws, the suction power from the plunger is applied equally to all surfaces of the underlying lung through the medium of the overlying fluid. This sudden negative pressure may cause an uneasy sense of tightness in the patient's chest, leading to respiratory difficulty or coughing spasm.

4. Seldom should more than 1,000 ml. of fluid be removed at one time. The resultant increased negative pressure may cause an infected or weakened region on the surface of the lung to blow out and tension pneumothorax to develop.

5. Serous fluids suspected of being tuberculous should not be evacuated without air replacements until culture studies have been made. It may be inadvisable to reexpand the lung.

6. A lung abscess should never be aspirated through the intact chest wall. Adhesions may not be present and a virulent pleural infection may result. As a corollary to this, it can be stated that it is dangerous to perform needle aspiration of the chest in any patient who is expectorating foul sputum.

7. As the needle is advanced in the chest wall the syringe should be held in the right hand and the needle in the left, with a gauze sponge at the level to which the needle is to be inserted. This will prevent too rapid or deep penetration if the resistance of the chest wall is suddenly overcome as the pleural cavity is entered.

There are three indications for thoracentesis which demand special consideration. They are:

1, tension pneumothorax;
2, hemothorax; and
3, empyema.

TENSION PNEUMOTHORAX

This condition arises due to injury to the lung. A valvular mechanism is established wherein air escapes from the point of injury on inspiration and is prevented from returning to the tracheobronchial tree. In this fashion an

lung which might cause one of three accidents; 1, hemorrhage, which is not likely because of the low blood pressure of the pulmonary circuit and the high content of thromboplastic substance in the lung tissue; 2, the escape of air into the pleural space, even to the point of development of a tension or valvular pneumothorax; or 3, infection by contamination of the pleural space with organisms contained in the lung.

The optimum point of aspiration of fluid from the pleural space, unless the roentgenographic interpretation indicates otherwise, is the eighth interspace posteriorly in the midscapular line. This is a dependent portion of the chest, yet not too dependent to the point where a high diaphragm might be injured. If a space below this is selected, then care must be taken that the needle is inserted at a point just within the pleural cavity. Figure 7-6 illustrates how injury of the diaphragm may occur if this precaution is not taken. Subdiaphragmatic abscesses have been aspirated through error, interpreted as being empyema. Contamination of a noninfected pleural effusion may occur as the needle is withdrawn.

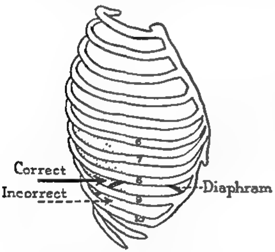

Fig 7-6. Schematic drawing of right lateral thorax. *Posterior thoracentesis* below level of eighth rib may plunge needle through the diaphragm unless introduction is made only through parietal pleura.

Technic of Thoracentesis. It cannot be too often emphasized that before thoracentesis is begun, the operator should have good anteroposterior and lateral roentgenograms of the patient's chest before him on a viewbox within the range of his vision. He must arrange his patient in a comfortable position, he must be comfortable himself, and the light must be adequate. All supplies needed in the procedure, such as sterile gloves, drapes, antiseptics, needles in duplicate in case one is dropped, 0.50 or 1 per cent novocain solution, sterile gauze, syringes, etc., must be on hand. The help of an assistant is important, in that the patient's arm on the side to be entered may be elevated so as to raise the scapula out of the way. It may be advantageous to bend the patient's body so as to widen a particular interspace or to steady the patient so that no movement shall come as the skin is entered or at any later time when by a sudden jerk a needle might be sheared in two by rib action. Furthermore, an assistant can steady a weakened patient, check on the quality of the pulse and in general be very helpful. A wheal is raised in the skin with novocain injected through a No. 24 hypodermic needle. Adequate quantities of novocain should be used. This needle is left in the skin. A No. 22 long needle is then placed upon the syringe and inserted into the tract from which the previous hypodermic needle

entering the chest, but mounting pressure within the chest [illegible] to escape through the opening.

Pitfalls and Precautions. 1. The assumption that an increased pressure within the pleural cavity to cause further lung collapse will allow for healing of the injured part, is sometimes faulty. The injury may be due to a torn adhesion. Further collapse may cause further tearing.

2. Suction may have to be continued for several days until healing occurs. Other accessory methods of treatment to heal an injured lung have been described.

HEMOTHORAX

It has been stated that death from hemorrhage into the chest can occur without serious disturbance of respiration. Hemorrhage into the pleural space has two sources of origin, the systemic and pulmonary circuits. In the latter if a very large hilar vessel is injured, death will occur without chance for aid. If bleeding is from the lung substance, however, this bleeding will soon cease because the mounting pressure of the effusion is sufficient to control the low pressure of the pulmonary circuit. The same holds true for venous bleeding from the chest wall.

If, however, chest wall injury occurs producing tearing of an intercostal or internal mammary artery, immediate action is indicated. The diagnosis of this condition is made on the recognition of a rapidly developing hemothorax which may require constant blood infusion to maintain blood pressure, plus evidence of injury of the thoracic parietes. Roentgenograms may aid in locating fracture points where these injured vessels may be looked for. They are then exposed by rib or costal cartilage resection and proximally and distally ligated under local anesthesia. It is possible under certain circumstances to control a bleeding intercostal artery by swinging an aneurysm needle around first one side and then the other of a fracture site in a rib, with each maneuver introducing a No. 1 chromic catgut suture which when tied may accomplish arrest of bleeding. This should be done under local infiltration anesthesia.

Replacement of blood during formation of a hemothorax in general should be guarded. The too liberal use of intravenous infusions may produce pulmonary edema and lower an already diminished vital capacity.

When intrapleural hemorrhage has ceased the question of aspiration of blood arises. In case of lung injury the hemothorax is potentially infected as it is when such hemothorax is produced by missiles and foreign bodies perforating the chest wall. There is almost always a moderate febrile reaction associated with hemothorax. If this is excessive, chemotherapy should be begun. Thoracentesis may be performed after 72 hours have elapsed from the time of cessation of hemorrhage. Small amounts of blood may be removed preferably with a large bore needle. Later a trocar may have to be resorted to, as described under the management of empyema by closed drainage. If repeated small 100 to 300 ml. amounts of blood are withdrawn, air replacement should not be necessary. Air replacement tends to keep a lung collapsed and should empyema develop the difficulties of dealing with total empyema are such that its avoidance is highly desirable.

In some instances the so-called two-needle technic may have to be em-

increasing degree of pneumothorax may rapidly develop, displacing the mediastinum, compressing the contralateral lung, and causing death by asphyxia.

The treatment depends on immediate recognition. This must be accomplished by physical examination of the patient. The time and effort spent in fluoroscopy may lead to death before treatment can be instituted. The pressure should be relieved at once by the insertion of a needle preferably through the anterior second interspace, about 3 to 4 cm. from the lateral border of the sternum. After withdrawal of air the interpleural pressure should be checked at intervals by the attachment to the needle by way of rubber tubing, of a pneumothorax manometer. If the pressure tends to in-

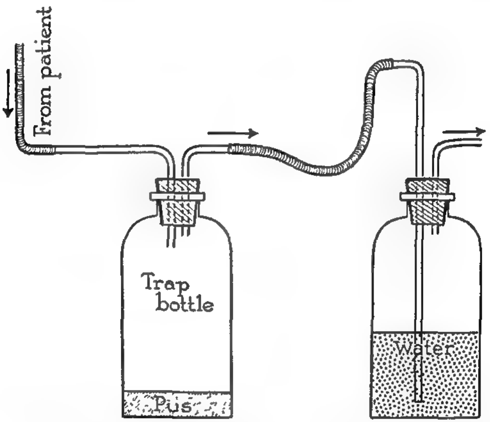

Fig 7-7. Two bottle water seal apparatus This has the advantage of 1, preventing the aspiration of fluid back into chest in case bottles are disturbed or improperly placed, and 2, measurement of drainage. The trap bottle and connection should be sterilized.

crease, the needle should be left in place, connected to a water seal apparatus as illustrated in Figure 7-7. The patency of the needle should be checked periodically and in the event that a water seal apparatus is used, a suction pump may be connected so as to periodically withdraw additional quantities of air. The needle must be firmly fixed to the chest wall with supporting dressings. It should be preferably of the short bevel variety of 22 gauge size. The second interspace is chosen in that it is readily accessible, high in the chest, and is a place in the thorax where there is less respiratory motion. A simple apparatus may be used, consisting of a needle with rubber and glass connections, over which a finger cot, with end perforated, may be tied. On inspiration the readily collapsing finger cot will prevent air from

liminary procedure in locating the empyema fluid. When this has been accomplished the needle is then withdrawn. At its point of entrance a 1 cm. skin puncture is made with the point of the scalpel. A sharp pointed trocar sufficiently large to transmit a No. 18 or 20 French catheter is then inserted as illustrated in Figure 7-8. The catheter should be so marked as to have an optimum length within the pleural space. There should be two eyes near its tip. After it has been fed through the trocar and the trocar removed it is then adjusted so that the most proximal eye is near the pleural surface. The catheter should be fixed to the skin by a suture which should not be tied so as to constrict the lumen. When available, a sponge rubber pad may be threaded down the catheter to the chest wall and taped in place. As a substitute for this maneuver a collar may be made of the flared end of another catheter. This is then placed around the catheter and taped against the chest wall to effect a snug and firm point of exit from the chest wall.

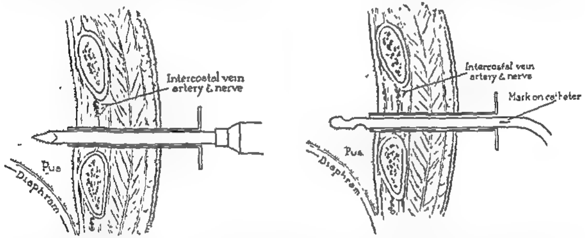

Fig. 7-8. Vertical section through posterolateral thoracic wall. Left, a sharp pointed trocar has been introduced into empyema pocket so as to avoid intercostal vessels above. Right, the removable penetrating point has been replaced by a suitably sized catheter. This has been marked at the proper point before introduction so that its perforated end will lie just within the pleural space. While held in this position, the trocar sheath is removed, leaving the catheter in place. Care is taken not to change the position of the catheter in so doing

The end of the catheter should then be connected by means of glass tubing and additional rubber tubing with the two-bottle set as illustrated in Figure 7-7. The connections in these bottles must be well fitting and the glass tube in bottle No. 2 must be well beneath the measured amount of water contained in that bottle The apparatus as well as the water should be sterile. It is kept at floor level, never high enough to allow aspiration back into the chest even on deepest inspiration. When these connections have been made the clamp which has kept the catheter closed during the operation is removed. When the first or trap bottle content is to be measured or emptied, the catheter should again be clamped. If drainage ceases unexpectedly the catheter should be irrigated with a few milliliters of sterile water, to be sure that there is no plugging.

In the treatment of empyema this catheter should be left in place until either the lung reexpands (three to six weeks) to the point where the catheter is forced from the sinus which it occupies or until open drainage is instituted, whichever the case may be. In the use of this apparatus in post-

ployed. A 22 gauge needle is inserted high in the chest, preferably at the level of the fourth or fifth interspace. Air is allowed to enter through this needle from a syringe or manometer connected with a pneumothorax apparatus. In this way increased negative pressure is equalized which may develop as a result of suction produced by pull of the plunger employed to aspirate blood from the lower chest through the second larger needle. This will obviate the blocking of the lower needle by clots which may be present in the pleural cavity which tend to impinge themselves upon the lower aspirating needle as fluid is withdrawn.

The care of chronic hemothorax with structural deformity and of subacute hemothorax requiring decortication will be discussed under subsequent headings.

CLOSED DRAINAGE TREATMENT OF ACUTE EMPYEMA

Thoracentesis has been mainly employed as a diagnostic procedure in pleural empyema. Occasionally in infants or in adults with small pockets of pus, aspiration alone may be sufficient as a therapeutic measure. As a diagnostic aid it may be used to withdraw enough pus to reduce toxicity until more definitive treatment can be carried out. However, there is danger of producing phelgmonous suppurative processes of the chest wall if repeated aspirations are made. These are more rarely seen now since the advent of chemotherapy. By aspiration the optimum time for open drainage of streptococcus empyema may be determined, that is, when the pus has become thick enough so that the sequelae of open pneumothorax may not produce dangerous physiologic disturbances. Pneumococcus pus, it is to be remembered, thickens earlier and allows therefore for earlier adequate drainage. Since the advent of antibiotics thoracentesis as a therapeutic treatment has been more widely employed. Organisms cultured from pus withdrawn from the chest may be successfully grown, if not inhibited by the antibiotic used in the treatment of the original pulmonary infection. If culture is successful, sensitization studies may be made and the antibiotic of choice selected. Complete aspiration of the purulent accumulation should be carried out with instillation of an antibiotic-containing fluid in the proper therapeutic concentration. Should the pus thicken before complete reexpansion has occurred, the proteolytic enzymes, streptokinase and streptodornase, may be employed along with the use of the intrapleural antibiotics. There will always remain those empyemas whose successful management will not depend upon antibiotic therapy but instead upon properly timed early and adequate drainage.

Catheter (Intercostal, Closed) Drainage. Closed drainage of the pleural space by catheter is indicated in those empyemas in which aspiration alone does not control the toxicity and in which open drainage would be dangerous because of the disturbance in pulmonary physiology due to open pneumothorax. It is employed usually in the streptococcus types of empyema. Otherwise, the more favorable results of open drainage are so well established that its use is much more widespread than that of closed drainage.

Closed drainage is prepared for as in thoracentesis which is the pre-

liminary procedure in locating the empyema fluid. When this has been accomplished the needle is then withdrawn. At its point of entrance a 1 cm. skin puncture is made with the point of the scalpel. A sharp pointed trocar sufficiently large to transmit a No. 18 or 20 French catheter is then inserted as illustrated in Figure 7-8. The catheter should be so marked as to have an optimum length within the pleural space. There should be two eyes near its tip. After it has been fed through the trocar and the trocar removed it is then adjusted so that the most proximal eye is near the pleural surface. The catheter should be fixed to the skin by a suture which should not be tied so as to constrict the lumen. When available, a sponge rubber pad may be threaded down the catheter to the chest wall and taped in place. As a substitute for this maneuver a collar may be made of the flared end of another catheter. This is then placed around the catheter and taped against the chest wall to effect a snug and firm point of exit from the chest wall.

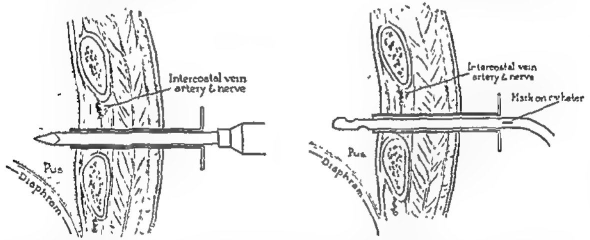

Fig. 7-8 Vertical section through posterolateral thoracic wall. Left, a sharp pointed trocar has been introduced into empyema pocket so as to avoid intercostal vessels above. Right, the removable penetrating point has been replaced by a suitably sized catheter. This has been marked at the proper point before ... just within the pleural space. ... the catheter in place Care is t...

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operative intercostal drainage the catheter should be left in place until drainage ceases (24 to 96 hours) or until it has been shown by roentgenogram that the lung has completely reexpanded. When such a catheter is removed a small pressure dressing is applied to cover the opening.

In children where restlessness may disturb the handling of such apparatus as has been described, the catheter is not attached to the water seal bottles. Instead it is clamped and protected in an adequate dressing applied to the child's chest. At hourly or two-hourly intervals a sterile syringe may be attached to it, the clamp removed and fluid evacuated. The catheter may be kept open by irrigation at these times with a few milliliters of sterile water. In the event that there is no bronchopleural fistula, both in adults and in children, irrigation of the pleural cavity may be accomplished using at first sterile water and later 50 per cent to full strength Dakin's or penicillin solution as may be the choice of the operator.

Pitfalls and Precautions. 1. Even more care should be exercised in the introduction of a trocar into the chest than in the similar introduction of a thoracentesis needle. It is obvious that the larger instrument can produce more damage if improperly placed. It should be inserted according to the anatomy previously described.

2. Catheters should be tested for patency by injection of sterile water into them and by aspiration of sterile water through them in the opposite direction. Rarely, there may exist diaphragms in the catheter lumen which might transmit fluid in one direction but block its return flow.

3. In youngsters whose illness has depleted their subcutaneous fat tissue and chest wall muscles, a catheter introduced through such a thin chest wall may fail to remain airtight for a sufficiently long time to be effective. This is particularly true if the patient is coughing excessively. Air will be sucked *into* the pleural space along the catheter wall and coughed out along the planes of the fascia covering the chest wall to produce a disturbing degree of subcutaneous emphysema. Despite the desire for the more adequate drainage which the catheter would allow, and despite the difficulties of repeated needle aspiration, the latter may well be the procedure of choice.

FUNNEL CHEST (PECTUS EXCAVATUM)

As the name implies, this is a funnel shaped deformity of the anterior chest wall (1). When the deformity is fully developed it is characterized by a deep conical depression of the anterior chest, the apex of which is at the xiphoid. The sternum shows the greatest displacement. The manubrium is approximately at the normal level but from this point the sternum curves sharply backward until the xiphoid approaches the vertebral bodies. In some instances the xiphoid has been practically in contact with the bodies of the vertebrae. The apex of the depression may be in the midline but is often to the right of it, thus making an asymmetric funnel. The ribs and costal cartilage attached to the sternum are proportionately involved in the deformity. The ribs tend to flare out laterally and to turn downward and backward at their sternal end. This is particularly noticeable with the upper ribs and gives a barrel shape on roentgenologic examination.

The effect of the deformity on the thoracic viscera is that of compression. The lung volume is decreased in proportion to the deformity but seldom to a critical level. The effect on the heart is proportionate to the pressure on it and not necessarily to the degree of deformity. Usually the depression of the sternum pushes the heart into the left hemothorax.

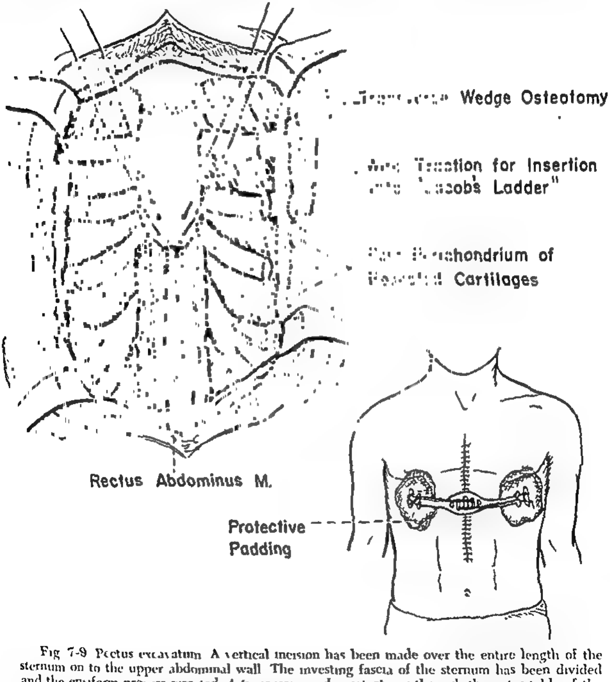

Fig 7-9 Pectus excavatum A vertical incision has been made over the entire length of the sternum on to the upper abdominal wall The investing fascia of the sternum has been divided and the ensiform process resected A transverse wedge osteotomy through the outer table of the body of the sternum will allow for satisfactory elevation of the body after resection of the attached costal cartilages The elevation is maintained through the use of wire-traction sutures inserted into the "Jacob's ladder" prosthesis

The movements of the thorax are the reverse of the normal respiratory movements. This was explained by Brown who has outlined the treatment on the basis of correction of the pathologic anatomy and disturbed physiology.

The surgical treatment is of two types; the first and more simple is used

in the early stages of the deformity in infancy and is designed to release the pull of the diaphragm on the sternum and costal arch. Through a vertical incision directly over the depressed ensiform process, this structure is exposed and the fibrous portion of the foreshortened diaphragm behind it is severed. This maneuver will be successful only in infants and the occasion for its employment will not be frequent. The second or more radical procedure is designed to correct the deformity which has been established. It must not only release the diaphragmatic pull but also correct the bony deformity which has resulted from this pull. Through a vertical incision extending from just below the suprasternal notch down on to the upper abdomen in the midline, an incision is made exposing the sternum, its costal cartilages and muscular attachments (Fig. 7-9). The ensiform process is resected as are the costal cartilages, bilaterally, preserving the posterior perichondrium. This allows for satisfactory elevation of the sternum to the degree that the transverse wedge osteotomy of the corpus will permit. This osteotomy is made in the anterior table. The sternum is kept in the elevated position with wire traction sutures which are attached to the "Jacob's ladder" appliance. The edges of the wound are to be approximated as illustrated. The wire traction sutures and appliance may be removed in from 10 to 21 days. For youngsters, to prevent trauma and activity causing recurrence, protective jackets are available(2). The reported results of these treatments have indicated that all patients have received relief from their pressure symptoms. The deformity may not always be satisfactorily corrected. The risk is not great.

HERNIA OF THE LUNG

The presence of a palpable orifice in the thorax through which a smooth, soft, crepitant, reducible hernia appears, the size and shape of which varies with respiration should make the diagnosis evident. Experiences(3) in repairing large defects of the chest wall justify the following conclusions:

1. Any defect of the chest wall regardless of size can *usually* be repaired by plastic procedures involving only structures which are part of the chest wall, namely, rib, periosteum, and muscle.

2. The most important feature in the repair of pulmonary hernias is covering the defect with sturdy bone or with periosteum which will produce bone. Ribs after division and release from their periosteal envelopes can be shifted to bridge the defect and anchored in the desired position by pericostal fixation, by suturing to fascia or adjoining periosteum or by fastening rib to adjacent rib with absorbable sutures threaded through drill holes. The most satisfactory repair of average size defects is obtained by the suturing of periosteal flaps developed from the ribs immediately above and below the hernial orifice.

3. The freeing of adhesions and of the lung about the margins of the hernial orifice combined with the creation of a local pneumothorax is important in producing a cushion between the lung and freshly repaired chest wall. This reduces to a minimum the possibility of the lung being forced into the chest wall by coughing and straining during the period when the repair is weakest.

4. Many defects of the chest wall associated with hernia of the lung

will in course of time become increasingly rigid, but the hernia although smaller will persist.

5. The intratracheal administration of the anesthetic agent is necessary when surgical repair of defects of the chest wall and hernia of the lung is attempted. This insures safety when the pleura is opened widely and also makes it possible to leave the lung in the desired degree of inflation.

OPEN WOUNDS OF THE THORAX

Injuries to the chest wall are dangerous in that they may result in the production of open pneumothorax, that is, a free communication between the pleural space and the outside air. The harmful effects depend upon the size of the communication which in turn reduces the vital capacity of the individual. On inspiration air is drawn into the pleural cavity. For this reason the condition is known as a sucking wound. An open pneumothorax is much more dangerous than a closed one. In the former not only are there serious pressure disturbances which affect the ability of both lungs to take in air, but also, because of the swinging motion of the mediastinum (mediastinal flutter), there is a movement of air from the more collapsed to the less collapsed lung during inspiration, and in the reverse direction during expiration. As a result both respiration and circulation are seriously impaired.

It is essential that open wounds of the thoracic wall be closed at the earliest possible moment.

First-aid Treatment. Immediate airtight closure by suture should be effected when possible. If because of excessive tissue loss or for other reasons it is not possible to close the opening by suture, it should be temporarily closed by adhesive plaster, rubber dam, a large pad of petrolatum gauze or moist dressings, or any other means at hand.

Definitive Treatment. An x-ray film should be made for the detection and localization of foreign bodies. If infection has not developed, thorough débridement should be performed, including removal of foreign bodies and devitalized tissue from the thoracic cavity and lung. If possible to do so without tension, the various layers of the thoracic wall should be approximated. If this is not possible, closure can be accomplished by one of the following methods:

1. If the wound involves the lower portion of the thoracic wall, the diaphragm can be paralyzed and then sutured to the margins of the wound. To paralyze the diaphragm the phrenic nerve is crushed transpleurally when possible or through the usual small supraclavicular incision in the neck (Fig 7-11).

2. In the upper portion of the thorax such broad heavy muscles as the pectoralis major, latissimus dorsi, or the trapezius can be mobilized and sutured over the defect. If none of these measures is applicable closure may be obtained by suturing the lung to the margins of the wound, then covering the area by gauze pack. The skin can be immobilized and advanced for suture by relaxing incisions.

3. Watson(4) has described the use of a fascia lata graft for large defects of the chest wall such as result from wide excision of tumor. A measured section of fascia lata is removed to fit the defect, sutured to pleura, perios-

teum of adjacent ribs, and intercostal bundle. The lung is expanded through underwater seal drainage so as to become adherent to the site of the defect.

If active infection already has developed, the tissues of the thoracic wall can be approximated snugly by the use of adhesive plaster. Suture of muscles or plastic operations bringing parts together under tension are to be avoided. In the presence of gross infection the opening can be closed by an adhesive pack made of rubber sheeting or of gauze impregnated with petrolatum. The pleural cavity itself should not be packed, or gauze placed against the mediastinum. The pleural space is drained by an intercostal catheter, preferably in a dependent position, away from the wound in the thoracic wall and connected with an underwater seal. When an occlusive pack is employed it is sutured to the skin so that it cannot be drawn into the chest. The patient is kept on the injured side until pleural adhesions form and the mediastinum becomes stabilized.

FRACTURE OF RIBS

Immobilization of the chest for the relief of rib fracture is the most effective method of treatment. This is accomplished preferably by the use of measured lengths of elastoplast bandage which encircle the affected side, beginning well beyond the midline in front and ending similarly well beyond the midline posteriorly. These should be applied when possible with the patient in the standing position, the arm of the affected side elevated and the chest in a position of complete expiration. In the event of multiple rib fractures with pain sufficiently great to seriously impair respiratory activity, it may be necessary to infiltrate the fracture site or perform a paravertebral block with 0 50 per cent novocain anesthesia as described under thoracentesis. If a longer acting anesthetic agent is desired, Eucapin in oil may be similarly used, as described by Harmon(5).

When trauma to the chest has been maximum, causing a caved-in or a crushed rib cage, more radical treatment is necessary. The use of towel clips to elevate the depressed thoracic wall is advocated. The skin and soft parts are infiltrated with 1 per cent solution of procaine, above and below the third and fifth ribs, 3 cm. lateral to the sternal border. Small incisions are made in the skin and an open towel clip is applied so that the costal cartilage is grasped between its jaws. One clip is placed around the third and one around the fifth cartilage The towel clips are attached by wire or heavy cord to 5 pound weights, running the cord or wire over a pulley suspended from an overhead frame, or short handled clips may be used and attached to a plaster jacket by rubber bands If a plaster jacket is used it must be padded so that at least 6 inches separate it from the anterior thoracic wall.

Pericostal sutures may also be used for this purpose. Local anesthesia is employed as described above. Small incisions are made in the skin, at least 3 cm. from the sternal border and a heavy, full curved needle armed with 12 inches of heavy stainless steel or silver wire is introduced. The needle is passed around the costal cartilage keeping the point close to the cartilage. It is then brought out through another incision in the skin. An aneurysm needle is perhaps a safer instrument. This may be passed around the rib

or cartilage, threaded with the wire and withdrawn. The third and fifth cartilages are used for this purpose. The wires are twisted or tied around a spreader made of three tongue blades fastened together with adhesive tape. A cord or wire is attached to spreader and a 5 pound weight is used for traction over a pulley.

A mechanical respirator if available may be of great assistance in the management of patients with extensive injury to the thoracic wall. They may need bronchoscopic aspiration and/or tracheostomy if signs of "wet lung" appear.

OPERATIVE DEFECTS

Operative defects of the thoracic wall may require treatment similar to that described above for the reestablishment of continuity. These operative defects are usually incurred in the resection of tumors of the chest wall. These tumors may arise from any one of the component parts of the thoracic cage and its soft tissue covering. The x-ray visualization of these tumors is of utmost importance. Whether they are primary or metastatic is obviously a determining factor in their treatment, if malignancy is suspected. Their removal should be carefully planned, using the data set down in the description of the anatomy of the chest wall. If the tumor is limited to a single rib and on biopsy is found to be benign, subperiosteal resection can be simply carried out. Regeneration of the rib will take place from the periosteum which remains. If the tumor of the rib is malignant, then adequate removal can be effected by a carefully planned and executed block dissection sacrificing ribs or costal cartilages, their periosteal coverings and the intercostal bundles between. In repair, use should be made of the principles established under the headings of Hernia of the Lung and Repair of Defects in the Chest Wall.

It must be recognized that trauma producing serious injury to the chest may also cause grave injury elsewhere. Life-threatening head injury may accompany rib fracture, as may dangerous trauma to the abdomen. The summation of the associated injuries obviously affects the prognosis. Immediate intercostal or paravertebral novocain block where respiratory difficulty may have been produced by the so-called wet lung should be almost routine. Tracheal catheter aspiration and if necessary bronchoscopy may be employed. If there is any doubt or too much difficulty experienced by the patient in the expectoration of retained secretion then tracheostomy should be done immediately The use of early tracheostomy is lifesaving and is coming to be much more widely accepted as one of the early procedures of choice. It should be done more as an elective procedure and less as a last ditch, terminal operation.

It is dangerous to completely remove the sternum without some replacement because of the impaired physiologic functions which result. It is important that a portion of the sternum remain along with its attached costal cartilages, so that stability of the thoracic cage will not be completely disrupted This does allow for resections of large parts of the sternum, however, to eradicate tumors which may be located so as to necessitate these resections.

INFECTIONS OF THE CHEST WALL

Infections of the soft parts of the thorax which arise through extension from intrathoracic disease may be treated by chemotherapy, as described under Thoracentesis for Empyema, incision and drainage or by specific therapy, as in the case of tuberculous or luetic infections, which is effective in the management of these specific diseases.

Osteomyelitis of the rib may develop as a sequel to intrathoracic disease and occurs also when a rib is bared of its protective periosteal covering. For this reason, it is essential never to leave an uncovered portion of rib or costal cartilage. In the case of an involved intercostal cartilage this structure in its entirety must be removed, sacrificing a portion of the rib to which it is connected, as well as the sternum at the region of its attachment. Because of the spread of disease from one cartilage to another through the connecting lymphatics it may be necessary to sacrifice adjacent cartilages whose early involvement may be manifested by careful inspection. Osteomyelitis of the rib is a common cause of chronicity in the treatment of empyema thoracis.

THERAPEUTIC PNEUMOTHORAX

This is the introduction of measured amounts of air into the pleural space, designated to relax the lung by reduction of the normal negative pressure which exists within the thorax. Its most common usage has been in the treatment of pulmonary tuberculosis. The modern methods of treatment since the advent of antibiotics and the establishment of the place of resection have considerably reduced this indication. However, it may be of distinct diagnostic value in the study of tumors or in the preliminary preparation of patients for pneumonectomy. The ordinary needles may be used to anesthetize the chest wall as described down to the parietal pleura. When the pneumothorax needle is applied to the syringe the skin should be incised with a sharp pointed scalpel to prevent plugging of the needle. A 16 to 18 gauge needle whose beveled end has been blunted and shortened is gently forced through the parietal pleura. A blunt needle will push the lung ahead of it rather than penetrate. Withdrawing the plunger of the syringe will indicate whether or not a blood vessel has been entered. If there is no show of blood, or air bubbles which would indicate perforation into an alveolus or bronchus, then the manometer connection may be attached. If no fluctuation is obtained, the bevel of the needle may be turned. A reading of −7 to −10 cm. of water with an increase of negative pressure on inspiration indicates the presence of the needle point in the free pleural space. Air may be allowed to flow from the pneumothorax apparatus (Fig. 7-10). A pressure reading should be taken frequently through the course of induction. From 150 to 300 ml. of air may be injected, depending upon the size of the patient. Additional air may be injected in this manner every day or every other day until satisfactory collapse is obtained. Fluoroscopic examination will determine this point. Refills may then be given at increasingly longer intervals as the air is absorbed less rapidly.

If a reading of less than −7 cm. of water is noted, the needle is probably

not in free pleural space. If after obtaining a proper reading, the pressure rises suddenly as air is injected, the needle has been allowed to move or only a small pocket type of pneumothorax limited by adhesions has been formed. In either case readjustment should be made.

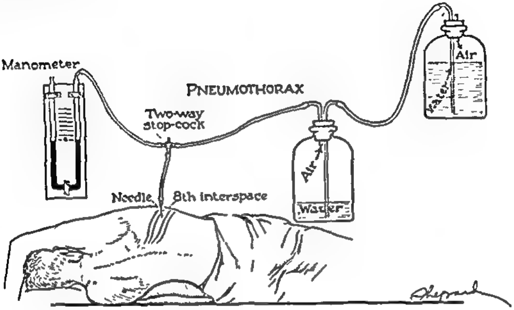

Fig. 7-10 Diagrammatic illustration of pneumothorax administration With the patient in [illegible]

America, Feb. 1942.)

Precautions and Pitfalls. 1. The sites of election of thoracentesis for therapeutic pneumothorax are (a) the eighth interspace posteriorly in the midscapular line, (b) the second interspace anteriorly, and (c) the fourth or fifth interspace in the anterior axillary line. If the lung is free of disease under these points they may be used. During induction injury to normal lung may cause no damage, but injury to tuberculous pulmonary tissue may have a far-reaching effect. If none of these regions is free, then it would be reasonable to consider another type of collapse therapy.

2. Never should air be injected into the thorax if proper respiratory oscillations are not obtained on the manometer. It is permissible to inject anesthetic solutions from the syringe, or compressed air in the tubing to separate the lung from the parietal pleura, but air in larger amounts may lead to air embolism.

3. Pleural reflexes are best abolished by the generous use of novocain, particularly at the level of the parietal pleura. The question of pleural shock has not been finally settled, but most incidents reported have been manifestations of the phenomena occurring in air embolism. In this instance it is assumed that the air is injected into the pulmonary circuit, thence to the left heart and the systemic circulation to travel to the cerebral arterioles or perhaps the coronary arteries.

4. It is best to continue to use the region in which the pneumothorax has been successfully induced.

PHRENIC NERVE INTERRUPTION

As has been said about pneumothorax, this operation has had its greatest application in the collapse therapy of pulmonary tuberculosis. However, it may serve as an adjunct in its effect of causing diaphragmatic elevation and diminution of the intrathoracic space after pneumonectomy. Likewise the elevated, relaxed diaphragm may be useful in aiding closure of defects of the thoracic wall caused by injury or surgical resection. Occasionally phrenic nerve interruption may be used to produce amelioration of the symptoms of diaphragmatic hernia when more radical treatment is contraindicated. Phrenic nerve crush should be employed preliminary to the abdominal repair of diaphragmatic hernia in adults.

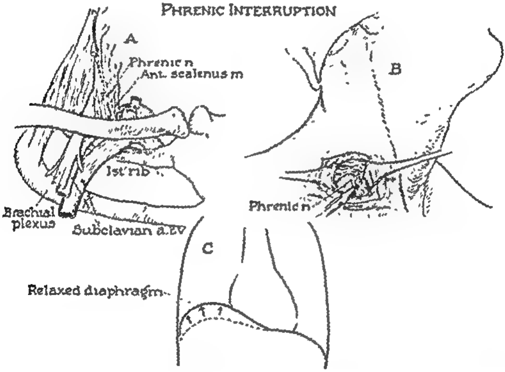

Fig 7-11 The anatomy of right phrenic nerve interruption. (From Dorsey, J. M. S. Clin. North America, Feb 1942)

Under local anesthesia an incision is made two fingerbreadths above the clavicle on the selected side extending lateral from the lateral border of the sternomastoid muscle, with the patient placed in position as for thyroidectomy. After the skin, subcutaneous tissue and platysma are divided and bleeding controlled, the patient's head is turned to the opposite side. The omohyoid muscle will come into view, and may be retracted upward or downward as proves most effective for exposure. The sternomastoid muscle and carotid sheath are retracted medially (Fig. 7-11) and retractors placed laterally and superiorly to open the field The cervical pad of fat is seen in the floor of the wound. This is separated by blunt dissection and the anterior scalene muscle felt with the palpating finger. The phrenic nerve is the only structure visible lying usually upon the muscle or in its fascial sheath running downward and inward It may be crushed with a small mosquito forceps for temporary (three to five months) paralysis of

the diaphragm or divided and a segment removed, for a permanent paralytic effect. Before crushing, and after slight stimulation during which the patient will complain of shoulder pain, for positive identification, the nerve may be infiltrated with 1 per cent novocain to reduce the pain of actual crushing. The test of operative success lies in postoperative fluoroscopic study. The diaphragm should be elevated, immobile or showing paradoxical motion.

Precautions and Pitfalls. 1. If the dissection is carried too far medially, the sympathetic chain will be encountered. This is recognizable in its straight course, and by its ganglia.

2. If the dissection is carried too far laterally, nerve branches of cervical origin may be encountered. Crushing of the sympathetic in the first instance will produce a Horner's syndrome. In the second, sensory or motor disturbances may result.

EXTRAPLEURAL THORACOPLASTY

Indications. Thoracoplasty is used for patients who are in at least fair general health, who have not had a recent exacerbation of their tuberculosis, and whose cardiac and respiratory functional reserves are adequate. Tuberculosis with cavitation which is moderately or far advanced, mostly confined to one lung and productive in character, in such patients presents the best indication for this operation; however, that is when pneumothorax or some other suitable operation has failed. There are many other considerations which govern the selection of thoracoplasty as a procedure of choice which are too detailed to mention in this discussion. The reader is referred to the splendid textbook by Alexander(6).

Technic of Operation. The modern thoracoplasty operation consists of the removal of posterolateral as well as anterior rib lengths in several stages for the purpose of producing collapse of the chest wall and therefore of underlying pulmonary tuberculous lesions. This is a permanent or irrevocable procedure. Either local or inhalation anesthesia may be employed. The patient is placed with the affected side upward, braced with sandbags, pillows and a broad adhesive tape strip across the hips. The head of the table is slightly lowered so as to allow secretions to drain toward the mouth rather than be aspirated into the opposite dependent lung. Blood may be added to the system when needed. The skin is prepared carefully from the cervical region to the hip longitudinally and from the sternum in front to the lowermost portion of the thorax behind.

The *incision* is illustrated in Figure 7-12. The muscles of the thoracic wall between the vertebral border of the scapula and the spine are divided by Carter's method, that is, while being grasped between the fingers of the operator and his first assistant. Bleeding points are secured by forceps as they are cut across. In this fashion the latissimus dorsi, the trapezius and the rhomboids are divided. The scapula is then retracted from the thoracic wall and the maximum exposure is obtained by stripping the attachments of the serratus magnus muscle from their costal insertions. This allows for excellent exposure of the upper ribs. If in doubt as to the number of ribs which might be safely resected in the first stage, the operator should pri-

marily remove the second rib from its vertebral attachment to the costochondral junction anteriorly. This allows for adequate exposure of the first rib. Adams(7) has revived the interest in the use of a paraffin pack with thoracoplasty. His results have been excellent and to date the disadvantages of the foreign body have not reappeared. With this technic the first rib may be preserved and a more adequate collapse obtained with a one stage operation.

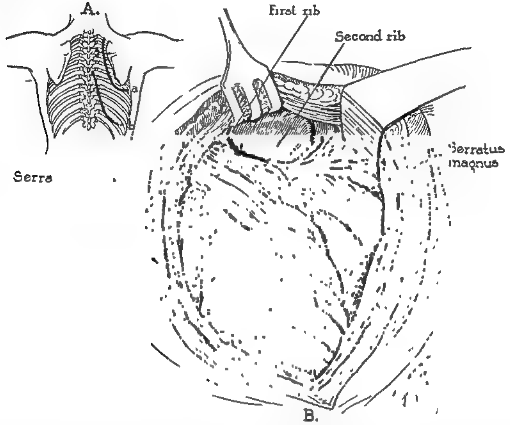

Fig 7-12 A, proper incisions for an eleven rib thoracoplasty. The ends of the strip of skin between the incisions are sufficiently broad to carry enough blood to the entire strip of skin so as to prevent cutaneous gangrene A retention suture is placed in the upper part of the incision to prevent dehiscence of the upper part of the incision if the lower part should be reopened for the second operative stage within 18 days of the first If only the upper eight ribs are to be resected in three stages, the superior of the two incisions may be used for all three stages. B, incision for a right-sided upper thoracoplasty. The scapula is being retracted posteriorly and laterally, putting the upper portion of the serratus magnus muscle under tension. Since this muscle is attached farther posteriorly to the second rib than to any other, retraction of the scapula causes the muscle fibers attached to the second rib to stand out as a crest This crest serves as a convenient identification mark for the second rib (From Alexander, J, *The Collapse Therapy of Pulmonary Tuberculosis*, Springfield, Ill., Charles C Thomas.)

All ribs except the first may be resected by the maneuver of *stripping* (Fig. 7-13). The first rib presents more danger and more difficulty in its removal because of its surrounding important anatomic structures which are, from behind forward, the scalenus medius muscle, the serratus muscle, the brachial plexus, subclavian artery, tendon of the anterior scalenus muscle, the subclavian vein, tendon of the subclavius muscle, the heavy costoclavicular ligaments, and the fibers of origin of the pectoralis major muscle. It is obvious that a careful subperiosteal resection of the first rib must be carried out to avoid these structures which are in its proximity. The posterior portion of the rib is cut across and the anterior dissection is carried

out by moving the rib backward and forward, held by a forceps, to allow for its best exposure. The anterior attachment is then severed.

It is important to point out the necessity for the *complete removal* of the ribs overlying tuberculous cavitation. This includes resection of the transverse processes which sometimes act as support, preventing adequate collapse of underlying cavities.

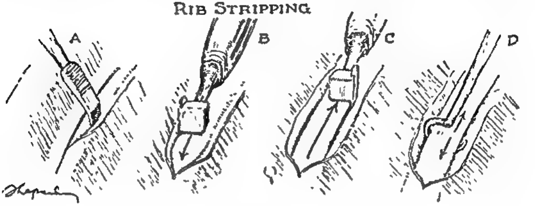

Fig. 7-13. Rib stripping. A, anterior costal periosteum divided and elevated with Alexander periosteal elevator. B, opposite end of instrument used to free periosteum from upper rib margin. C, periosteum freed from lower rib margin. Because of the direction of fibers of the intercostal muscles, the instrument should be swept downward (sternalward) along the upper rib border, and backward (vertebralward) along the lower margin of the rib Care must be taken to stay within the periosteal sheath to avoid injury to the intercostal vessels under the lower border of the rib. D, a Doyen periosteal separator placed beneath the rib to separate the posterior periosteal attachment. (From Dorsey, J. M S Clin. North America, Feb. 1942.)

After resection of ribs, the wound is closed in layers without drainage. In this fashion the accumulation of serum adds to the efficiency of the collapse. It is seldom wise to remove more than three ribs at the first stage of the operation. The usual interval between stages is from two to three weeks. Second, third and fourth stages may be performed to remove as many as 10 or 11 ribs. It is possible to do three stages through the incision indicated. A fourth stage in which ribs below the seventh are removed is best done through a separate incision (Fig. 7-12 A).

Postoperative Care. In the postoperative care, careful attention is paid to respiratory efficiency; oxygen is used when necessary, and pain is controlled adequately but sedatives are not given in quantities sufficient to abolish an effective cough reflex.

OPEN OPERATION FOR ACUTE EMPYEMA

Rib Resection. The advent of chemotherapy and antibiotics has made suppurative pleurisy or empyema thoracis a vanishing disease. Nevertheless, the principles of its treatment are an essential in the surgeon's armamentarium. They embody the fundamentals of thoracic physiology as well as those of wound healing. The site must depend on the localization of the pus and the confirmatory thoracentesis performed as a first step. As in thoracentesis previously described, the patient is kept in a sitting position while the needle is introduced. When pus is obtained, the patient is placed with the affected side uppermost and the chest wall prepared according to the choice

of the operator. A field large enough to allow for the resection of at least two ribs is demarcated by infiltration with 0.50 per cent procaine solution. Procaine is similarly infiltrated along the line of the incision proposed to remove the rib adjacent to the needle used in thoracentesis, which has been allowed to remain. The skin is incised for about 8 to 10 cm. Further infiltration of the muscles and intercostal spaces above and below the rib is accomplished as the operation proceeds. When the rib itself is exposed, 1 per cent procaine is injected with a fine needle under the periosteum overlying the rib. The periosteum is then elevated as illustrated (Fig. 7-13). Ten milliliters of 1 per cent procaine is then used to block the adjacent intercostal nerve proximally and distally, care being taken not to enter the intercostal blood vessels. A small segment of rib is then removed up to the limits of the portion bared of periosteum. Through the posterior periosteum, thoracentesis is then carried out again to be doubly sure of the site of the underlying empyema pocket. If again pus is obtained, a small incision is made with a sharp scalpel and an opening large enough to admit the examining finger is produced. It is to be remembered that the parietal pleura will be much thickened by the underlying inflammatory process. It should be noted here, too, that the shape of ribs overlying empyema cavities is changed from the usual flat configuration to that of a triangular one which somewhat increases the difficulty of resection, in that the rib instruments do not conform as well to the shape of the rib for purposes of stripping of the attached structure. The operator's finger is then inserted into the opening made in the parietal pleura, meanwhile removing the thoracentesis needle By finger exploration the size, shape and extent of the empyema cavity can be determined. Except for very small collections of pus it is usually advisable to remove segments of two ribs with the intercostal bundle as illustrated in Figure 7-14. For this reason the step involving finger exploration is a very important one because it determines the extent and direction of further resection. Enlargement of the original incision may be necessary to adequately unroof the empyema cavity. The purulent contents may be removed by aspirator and if fibrin collections are found, they can be similarly lifted from the pleural space gently with gauze sponges or with long tissue forceps. It is best to use the aspirator to evacuate the pus while the opening in the parietal pleura is small so that coughing or straining will not blow pus inadvertently from the operative wound. If a bronchopleural fistula exists, air may be heard whistling from the small openings if the patient is asked to strain with the nares occluded. In the presence of bronchopleural fistula, of course, no irrigation should be carried out. Otherwise the cavity may be lavaged with sterile distilled water or physiologic saline solution. It is then packed open as illustrated in Figure 7-14 with petrolatum gauze. The packing should be loosely placed so as not to plug the opening and prevent the escape of secretions.

The postoperative treatment consists of removal of the petrolatum gauze packs at the end of 48 hours After irrigation of the cavity, these are then replaced with gauze packs soaked with physiologic saline, noting the amount of solution used so that the size of the cavity may be followed from day to day. This, of course, cannot be done if bronchopleural fistula exists. After several days half strength Dakin's solution may be used and finally full

strength Dakin's solution in the irrigating fluid as well as in the gauze. This gauze pack should be snug enough to prevent the soft tissues of the thoracic wall from healing in so rapidly that the direct visualization of the underlying empyema cavity will be interfered with. If this does occur, plastic revision of the wound will be necessary to eliminate this disadvantage.

In small empyema pockets open drainage may be satisfactorily instituted by simple insertion of a large rubber tube into the opening made in the parietal pleura through the periosteal bed of the resected rib. This tube should be fixed by sutures to the intercostal tissues and should be marked by a safety pin. It may be shortened as the cavity decreases in size and irrigation may be performed through it if permissible.

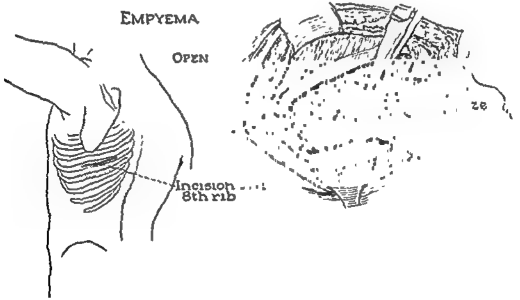

Fig. 7-14. Open drainage of empyema. Segments of two ribs have been removed and the intercostal bundle between excised after transfixion ligature of the vessels, proximally and distally. Portions of the posterior periosteum above and below remain. In this way adequate visualization of the cavity is obtained. Petrolatum gauze is packed into the wound and placed so as to protect freshly incised wound edges, and not plug the opening. Secretion will drain from wound. Frequent changing prevents plugging of the wound if it is properly made primarily in proportion to the size of the cavity. (From Dorsey, J. M. S. Clin. North America, Feb. 1942.)

Rib Resection with Utilization of a Skin Flap (Eloesser). This operation is particularly adaptable to war surgery. Once established it demands no more attention and there are no tubes to drop out or, worse, to drop into the chest and be forgotten. Properly performed the incision will not close until the lung has expanded to meet it. With the patient seated so as to be properly supported or lying affected side up, a U-shaped flap of skin and subcutaneous tissue is outlined (Fig. 7-15). Its base is 1½ to 2 inches wide and lies along the line of the rib to be resected, usually the eighth. The sides of the flap are 2 to 3 inches long, shorter for thin men, longer for fat ones. Procaine anesthesia is used, after which the flap is cut and lifted with a towel clip. The flap includes skin and subcutaneous tissue only, not the muscle. Two sutures of chromic catgut are put through its corners, each armed with a small curved cutting needle. Procaine is injected into the soft parts and intercostal spaces and 2 inches of the rib are resected. The pleura is incised and the pus aspirated. The chromic sutures of the

flap are passed through the pleura. By tying them the skin flap is tucked into the chest and held against the pleura. Corners of the U-shaped defect in the skin are closed with sutures so that the U is converted into a narrow transverse slit. A gauze dressing with a large mass of petrolatum is laid over

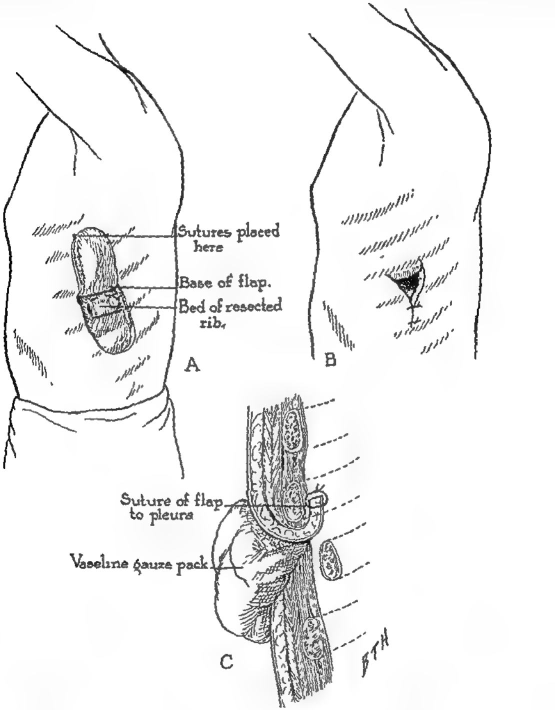

Fig 7-15 The Eloesser skin flap operation for empyema Two chromic catgut sutures are placed as indicated, and are used to suture skin flap to parietal pleura within the pleural space. It is safer to use needles attached to suture lest they be lost within pleura space.

the wound and held in place by a bandage The outer dressing may be changed but the inner ones remain for four or five days. The flap acts as a valve so as to allow the contents of the chest to escape readily but makes it difficult for air to enter the pleural space, allowing the lungs to expand

rapidly. Should the flap swell at first, it may be lifted every day or two in order to let the contents of the empyema cavity escape. When the lung has expanded it meets the tip of the flap and the wound is converted into a small funnel in the soft parts of the chest.

OPERATIONS FOR CHRONIC EMPYEMA

It is necessary to obtain adequate drainage as the first step in the treatment of chronic empyema rather than to proceed with any major cutting operation because many large empyema cavities can be considerably reduced in size by the institution of adequate drainage, leaving a much less radical procedure to eliminate the residual cavity. Such drainage may be obtained by the use of an intercostal airtight tube over which has been placed a nicked finger cot, as has been described by Lilienthal. On coughing or straining the pus will be forced out, but on inspiration the finger cot collapses and prevents the aspiration of air into the thoracic cavity.

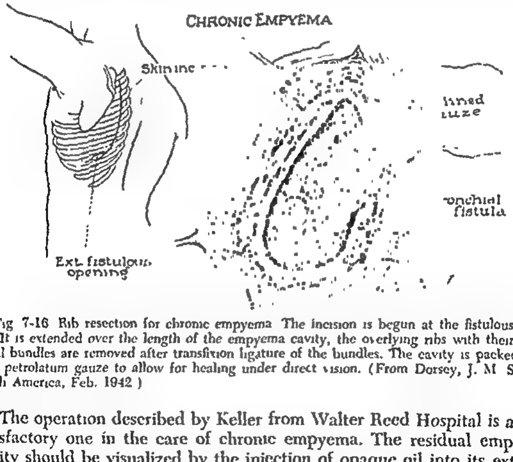

Fig 7-16 Rib resection for chronic empyema The incision is begun at the fistulous opening It is extended over the length of the empyema cavity, the overlying ribs with their intercostal bundles are removed after transfixion ligature of the bundles. The cavity is packed open with petrolatum gauze to allow for healing under direct vision. (From Dorsey, J. M S Clin North America, Feb. 1942)

The operation described by Keller from Walter Reed Hospital is a very satisfactory one in the care of chronic empyema. The residual empyema cavity should be visualized by the injection of opaque oil into its external sinus and anteroposterior and lateral roentgenograms taken to demonstrate the limits of the cavity. Resection of the thoracic cage overlying the cavity at its most dependent portion is begun by widening the sinus tract. All the overlying ribs are resected so as to expose completely the cavity when the thickened parietal pleura between the ribs is removed. This is dissected away after first transfixing the intercostal vessels with heavy chromic sutures both proximally and distally. The cavity thus prepared is cleansed, curetted if necessary, and some of its wall sent to the laboratory for microscopic examination to rule out tuberculosis. The wound is then packed open with

petrolatum gauze (Fig. 7-16). The completely unroofed cavity is then allowed to fill in spontaneously without further surgical procedures, except that daily dressings are carried out.

DECORTICATION AFTER HEMOTHORAX (8)

Although decortication is performed for the extreme fibrosis following chronic and tuberculous empyema, it is more often indicated for the fibrosis encountered following hemothorax.

The operation of decortication entails open thoracotomy. Clot evacuation alone is not a sufficient procedure. Associated lesions of the thoracic wall, lung or mediastinum are dealt with as may be indicated. The important technical considerations are:

1. Meticulous establishment of the cleavage plane between the peel and visceral pleura;
2. Careful blunt dissection of the peel either distally or by gauze dissector;
3. Complete freeing of the lung where it is directly adherent to the thoracic wall, to the mediastinum or along the fissural margins, so that complete circumferential expansion may be obtained;
4. Decortication and mobilization of the elevated fixed diaphragm with particular attention to redeveloping the costophrenic sulcus; and
5. Deliberate intermittent expansion of the lung under increasing positive pressure with careful stroking of atelectatic areas.

Attempts at immediate complete pulmonary expansion are ill-advised. On removal of the constricting peel there is exposed a grossly normal, thin, translucent, expansible pleura. A considerable amount of oozing occurs, readily explained when it is remembered that numerous capillaries are torn and left with gaping ends on the pleural surface. The bleeding is immediately controlled by expanding the lung with slight positive pressure. Attention is called to the greater thickness and vascularity of the peel which is adherent to the parietal pleura. Removal of this membrane has not resulted in any significant increase in thoracic wall mobility. The bleeding has been relatively severe and, of course, not controlled by pulmonary reexpansion.

Thoracotomy is performed through the bed of the resected sixth to eighth ribs under endotracheal anesthesia. Exposure is obtained by the use of the rib spreader. The dissector is a pledget of gauze held in the grasp of a long curved hemostat. Thoracentesis should be performed in the first few postoperative days to evacuate that fluid which may be present and which, if left, would interfere with the complete expansion of the lung.

OPERATIONS FOR LUNG ABSCESS

Lung abscess most often results from one of the following processes: 1, aspiration of infected material into the bronchial tree; 2, pneumonia; or 3, from an infected embolus lodging in the branches of the pulmonary artery. The location of the first type is usually lower lobar, with the right lower predominating because of obvious anatomic reasons. After pneumonia the involvement is that of the pulmonary area affected. Embolism

may occur in any region but the periphery of the lung is most commonly affected since infected emboli lodge most commonly in small vessels.

The treatment is first prophylactic. Secretions are prevented from being aspirated by the use of local anesthesia, as in tonsillectomy, thus preserving the cough reflex, by suction in the tracheobronchial tree during the course of surgery or by postoperative bronchoscopic drainage when infected secretions are present. In the debilitated or postoperative patient, gastric contents are kept from spilling over into the trachea by the use of the Levine tube to empty the distended stomach. Chemotherapy and antibiotics have reduced the incidence of lung abscess after pneumonia.

If symptoms are severe, or a spreading process is present, strenuous postural drainage should not be attempted. Such a patient should be allowed to lie on the diseased side. This will diminish cough and splint the affected side, preventing spread and allowing fever and toxicity to abate.

After localization has taken place, a trial of conservative management may be instituted, using postural drainage, chemotherapy, bronchoscopic aspiration and other general measures such as blood transfusions, high caloric and high vitamin diets, in the event that resolution and healing may be accelerated. Such treatment should not be persisted in if improvement does not result. Surgical drainage should then be instituted for it is recognized that prolonged nonsurgical treatment is always reflected in a high surgical mortality.

Localization of the lung abscess by careful roentgen studies is of utmost importance. Stereoscopic, lateral and oblique views as well as laminographs should be made to satisfy the surgeon as to the proper approach. It is to be remembered that there may be a slight difference in level between an abscess on an x-ray film taken in the standing position and the same one in the chest of a patient being operated in the recumbent position. Obviously, the level will be higher with the patient recumbent.

One-stage Drainage. After satisfactory localization has been accomplished, under local anesthesia, an incision is made down to the rib at which level the abscess had been demonstrated to lie. A short segment of the rib is removed with one or two adjacent intercostal bundles, as has been described. It is usually possible to determine by direct inspection and palpation whether or not adhesions are present between the parietal and visceral pleural layers. If the lung is seen to move beneath the parietal pleura, obviously then no attachment in this area is present. If the operator is satisfied that he has made his approach at the proper level, a very small incision is made in the pleura; occasionally the free pleural space may be opened, and the area of more firm adhesion detected nearby. If this is the case, then the opening of the pleura is closed with a mattress suture after the withdrawal of air with a catheter. An adjacent incision is made, or a rib above or below is resected, and the abscess cavity entered with an aspirating needle. Once pus is obtained in this fashion, then a hairpin cautery, scalpel, or pointed forceps is used to enlarge the needle tract and obtain an opening large enough for adequate drainage. The abscess cavity is then packed with gauze moistened with saline solution. It is important to be sure that rib ends are not left bare of their periosteal covering, because they will be readily subject to infection from the drainage wound. It is best

to keep them protected at all times, both by sponges during the incision and later by the gauze pack which is left in place for at least 48 hours. The wound should be dressed at the end of three to four days and the gauze replaced by a fresh pack. This is changed daily. When the wound has been properly prepared in this fashion, it will then be possible to use a soft rubber tube (pierced with a safety pin) which is long enough to reach to the pleural surface. Thereafter it is better to leave the drains in long enough to be sure that the abscess cavity is completely obliterated.

Two-stage Drainage. If in the event that adhesions are not found to be present at all when the pleural space is first opened or, if the operator on seeing lung move beneath the parietal pleura believes a one-stage operation unsafe, then he may place a pack of iodoform gauze against the parietal pleura. A small lead marker may be left with this pack, so that roentgen studies may be repeated to be sure that the area through which the approach has been made is the proper one. After five to seven days, the pack is removed and the aspirating needle may be introduced as described.

The surgeon can most often determine from the history of chest pain and chest wall tenderness, as well as the appearance of the x-ray, whether or not a region of adhesions of considerable size is to be expected. Since most lung abscesses are peripheral it is to be expected that adhesions will be present early.

Postoperative Treatment. It is important that the general condition of the patient be maintained in the postoperative period by the use of blood transfusions when necessary, the continued use of antibiotics and sulfonamides plus the maintenance of adequate nutrition. If these factors are taken care of reexpansion of the lung and healing will usually be uneventful.

Complications. Lung abscess when first seen may be of the chronic variety. These often present great difficulties in their treatment. It may be that their size and location will demand that primary lobectomy be carried out. The reason for this is that even after adequate drainage has been accomplished, multiple draining bronchial fistulas will be present, closure of which can be accomplished only with great difficulty. Since extirpation of a lobe of the lung has come to be accomplished with decreased mortality, lobectomy is considered to be even a conservative method of treatment for these abscesses. This is equally true of upper and lower lobe abscesses. Those who have had the experience of treating an upper lobe abscess with drainage through a wound in the axillary region, will realize that primary extirpation of the upper lobe is a simpler procedure.

Brain abscess is a frequent complication of suppurative pulmonary processes. Its incidence is particularly frequent after surgical intervention, if adequate drainage has not been accomplished. The brain abscesses which arise associated with these processes are different than the usual primary or metastatic brain abscess in that they tend to be more diffuse and rapidly fatal.

Bronchial fistula is most often present for a time at least after the drainage of a lung abscess. After all, the presence of a fluid level in the lung abscess which is one of the diagnostic roentgen signs, indicates the

communication with the bronchus. These bronchial fistulas ordinarily heal spontaneously when adequate drainage has been established. When, however, they are multiple and large, as seen in abscess cavities of considerable size, then, after they have become clean, collapsing operations and muscle grafts may have to be carried out in order to close them satisfactorily.

The mortality of lung abscess has been high, ranging from 15 to 40 per cent in reported series. It is a dangerous disease due to the inherent risk of the underlying etiologic processes, because it produces inanition in the patient, and because of the danger of cerebral complications.

With the more frequent use of one stage drainage and the employment of lobectomy or segmental resection in complicated cases, the mortality has been reduced to under 5 per cent and the cure rate increased correspondingly. The technic of lobectomy and segmental resection is described under Lobectomy.

Precautions and Pitfalls. 1. Preoperative bronchoscopy is an essential. Not only is it helpful for purposes of drainage but it serves to detect intrabronchial processes which may be the underlying cause of the abscess.

2. Opening of the abscess should not be too long delayed.

3. Aspiration of a lung abscess should never be carried out through the intact chest wall.

PULMONARY RESECTION

Anatomy. Birnbaum(9) in his recent *Anatomy of the Pulmonary Vascular System*, dedicates his work "To the pioneers and indefatigable workers, in the laboratories and medical and surgical clinics, whose inspiration and toil have advanced, and are ever advancing, the art and science of thoracic surgery." It is impossible in a text such as this to mention all such workers. Obviously the names of Graham, Rienhoff, Churchill, Blades and Kent, Overholt, Boyden, and Clagett, to mention only a few, should be called to the reader's attention. Their advancement of clinical thoracic surgery has resulted from their applying the knowledge of pulmonary anatomy contributed by such pioneers as William Snow Miller. Pulmonary resection has become as specific as radical mammectomy, gastrectomy, colectomy, or neck dissection. Figure 7-17 illustrates the divisions of the tracheobronchial tree and the related subdivisions of the lung which each supplies. These in turn are further subdivided into subsegments. They have a constant vascular pattern both arterial and venous which has been carefully worked out permitting the resection of single or multiple small segments of pulmonary tissue. The figures which follow illustrate the essential anatomic systems, the knowledge of which is essential to the performance of pulmonary resection. For a more detailed description of the anatomic variance the reader is referred to the recently published review of Birnbaum. The bronchial terminology of Jackson and Huber(10) has been employed. The segmental bronchi are as significant as the lobar divisions. The bronchopulmonary segments may be characteristically involved by certain disease processes. Accurate segmental localization is accomplished by the usual means of study with x-ray, bronchography and bronchoscopy. The most common pattern con-

to keep them protected at all times, both by sponges during the incision and later by the gauze pack which is left in place for at least 48 hours. The wound should be dressed at the end of three to four days and the gauze replaced by a fresh pack. This is changed daily. When the wound has been properly prepared in this fashion, it will then be possible to use a soft rubber tube (pierced with a safety pin) which is long enough to reach to the pleural surface. Thereafter it is better to leave the drains in long enough to be sure that the abscess cavity is completely obliterated.

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sists of 10 bronchopulmonary segments on the right side and eight on the left side.

THE BRONCHIAL TREE

Bronchi of the Right Upper Lobe. The right upper lobe is divided into three bronchopulmonary segments (Fig. 7-18): the apical, the anterior, and

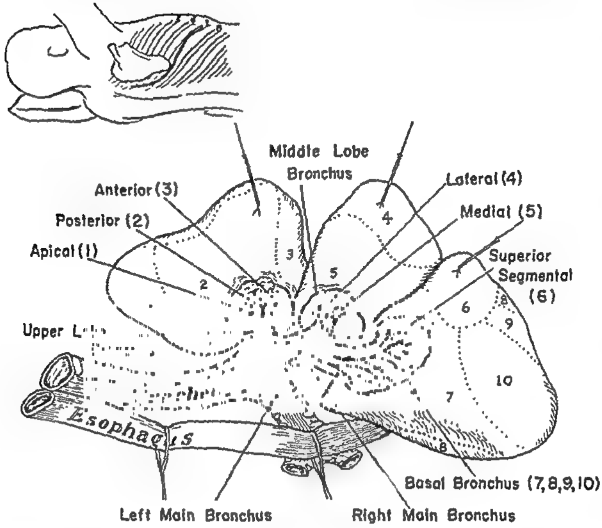
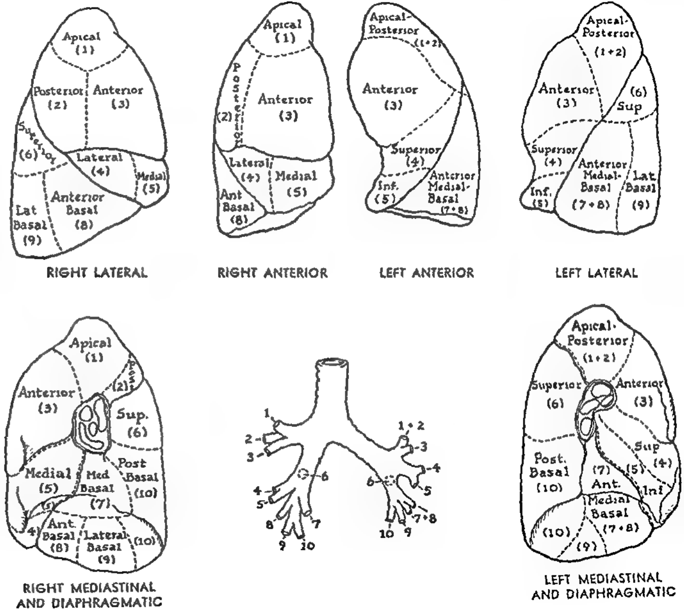


Fig 7-18 Bronchi of the right lung.

the posterior. The upper lobe bronchus arises close to the bifurcation of the trachea. It is very short and branches immediately. The precise localization of tuberculous lesions emphasizes the vulnerability of the posterior and apical segments for cavity formation. Two of the subdivisions of the segmental bronchi of this lobe are of special interest. Branches of the anterior and posterior segmental bronchus which supply the region of the axilla are the most common sites of lung abcess in the upper lobe.

Bronchi of the Middle Lobe. The portion of the right bronchus between the orifice of the upper and middle lobe bronchi is called the bronchus intermedius It varies from 10 to 15 mm. in length The middle lobe bronchus comes off from the anterolateral aspect of the bronchus intermedius at almost the same level as the superior segmental bronchus of the lower lobe. At times the middle lobe bronchus may arise at a slightly lower level. This bronchus is usually 5 to 12 mm in length and then divides into its medial



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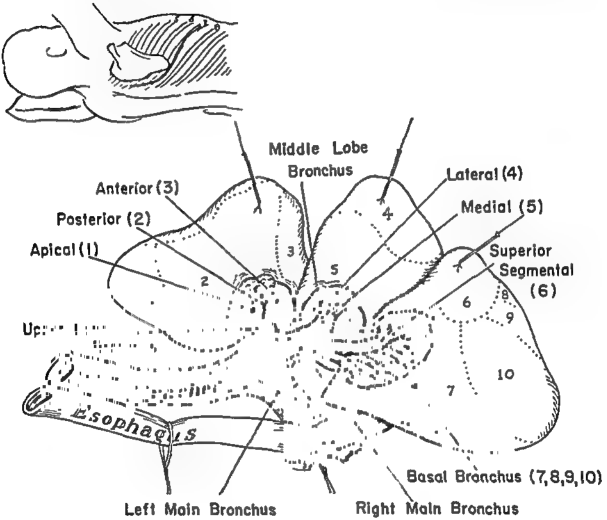


Fig 7-18 Bronchi of the right lung.

the posterior. The upper lobe bronchus arises close to the bifurcation of the trachea. It is very short and branches immediately. The precise localization of tuberculous lesions emphasizes the vulnerability of the posterior and apical segments for cavity formation. Two of the subdivisions of the segmental bronchi of this lobe are of special interest. Branches of the anterior and posterior segmental bronchus which supply the region of the axilla are the most common sites of lung abcess in the upper lobe.

Bronchi of the Middle Lobe. The portion of the right bronchus between the orifice of the upper and middle lobe bronchi is called the bronchus intermedius. It varies from 10 to 15 mm. in length. The middle lobe bronchus comes off from the anterolateral aspect of the bronchus intermedius at almost the same level as the superior segmental bronchus of the lower lobe. At times the middle lobe bronchus may arise at a slightly lower level. This bronchus is usually 8 to 12 mm. in length and then divides into its medial

and lateral branches. It will be noted that the right lower lobe has been drawn downward and forward displacing downward the superior segment number six. On careful inspection, however, it can be seen that the bronchus to this segment does arise at about the same level as the bronchus or bronchi to the right middle lobe.

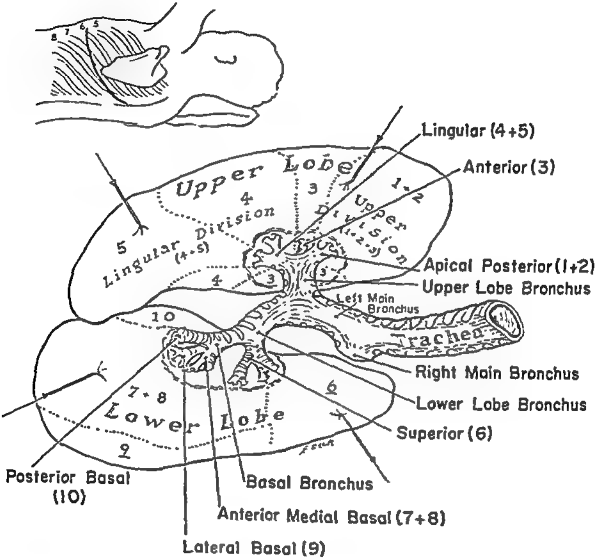


Fig 7-19 Bronchi of the left lung.

Bronchi of the Right Lower Lobe. There are two large divisional bronchi from the lower lobe bronchus: the superior segmental and the basal bronchus. The superior bronchus arises from the posterior and lateral aspect of the main bronchus at the origin of the lower lobe bronchus and at the level of the middle lobe bronchus or slightly above it. The surgical significance of this anatomic feature deserves special comment. When a lower lobectomy is being performed, the bronchus to the superior and basal segments should be divided separately in order not to obstruct or injure the middle lobe bronchus. The basal divisional bronchus constitutes in reality the prolongation of the main bronchus. It has a common stem which branches into four segmental bronchi The basal segmental bronchi are: the medial, the anterior, the lateral, and the posterior.

Bronchi of the Left Upper Lobe. The left upper lobe bronchus divides into two main divisional bronchi designated as upper and lower (lingular) divisions as illustrated in Figure 7-19. The upper division has an ascending course and divides into two segmental bronchi: the apical posterior and anterior bronchi. The apical posterior segmental bronchus branches into two subsegmental bronchi, the apical and the posterior considered by some authors as individual segments. Tuberculous cavities are most frequently found in these segments. The anterior segmental bronchus gives off a lateral subsegmental branch which ventilates an area of clinical importance. In this segment abscesses of the left upper lobe are most frequently found.

The inferior lingular division or lingular division is considered anatomically and clinically the counterpart of the middle lobe on the right. This divisional bronchus takes origin from the inferior aspect of the left upper lobe bronchus. The lingular bronchus has a descending and anterior course. It divides into two segmental bronchi: the superior and the inferior branches. Figure 7-20 illustrates variations in the mode of origin of the branch bronchus to the lingular and axillary division of the upper lobe bronchus; the pattern shown in A is noted to be more common.

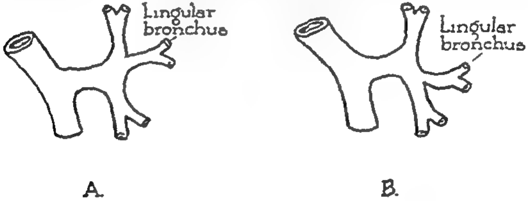


Fig. 7-20. ... gin of the branch ... the pattern shown ... 109.455, 1939.)

Bronchi of the Left Lower Lobe. Two large divisional bronchi arise from the lower lobe bronchus as is found on the right: the superior and the basal bronchi. The superior segmental bronchus arises from the posterolateral surface of the left bronchus about 5 mm. below the level of the upper lobe bronchus. The basal segments—anteromedial, anterolateral, and posterobasal—originate from a common stem and constitute the prolongation of the left bronchus. The proximity of the origin of the superior segmental bronchus to the upper lobe orifice warrants special mention. In performing a lower lobectomy it is often safer as on the right side to divide the basal and segmental bronchus separately rather than the main stem above the origin of the superior divisional bronchi.

THE PULMONARY ARTERIES

The main pulmonary artery divides into right and left branches for the right and left lungs at the level of its middle third on the anterior aspect of the left main bronchus.

Right Pulmonary Artery. Anatomically, the right pulmonary artery is longer than the left because of the division of the main pulmonary artery *into right and left branches to the left of the midline* (*Fig.* 7-21). For the intrapericardial course of this vessel (11, 12), the reader is referred to Figure 7-22. Its course is horizontally and slightly downward from its origin to enter the pulmonary root. It lies superior to the left atrium and posterior to the aortic arch and superior vena cava. It is also inferior to the aortic arch and azygos vein from left to right. The artery lies slightly anterior to the left bronchus and completely anterior to the right bronchus. The right

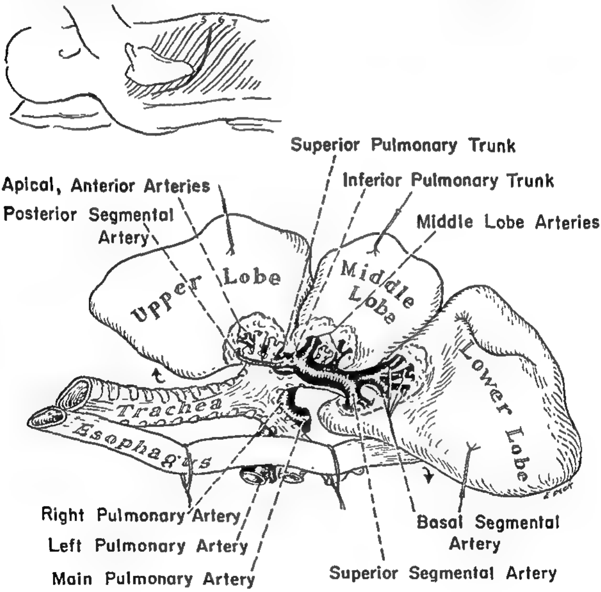


Fig 7-21 Right pulmonary artery and its branches.

pulmonary artery and the pulmonary hilum is anterior and inferior to the right bronchus and posterior and superior to the pulmonary vein. The right pulmonary artery in the root of the lung divides into two trunks, the superior and the inferior. The superior pulmonary trunk constitutes the common stem artery to the apical and anterior bronchopulmonary segments. It is the main supply of the upper lobe. This distribution is clearly shown in Figure 7-23. The inferior pulmonary trunk is the part of the pulmonary

artery which, deep in the interlobar fissure, supplies the middle and lower lobes. It also supplies the posterior bronchopulmonary segment of the upper lobe through the posterior segmental artery as indicated in Figure 7-21.

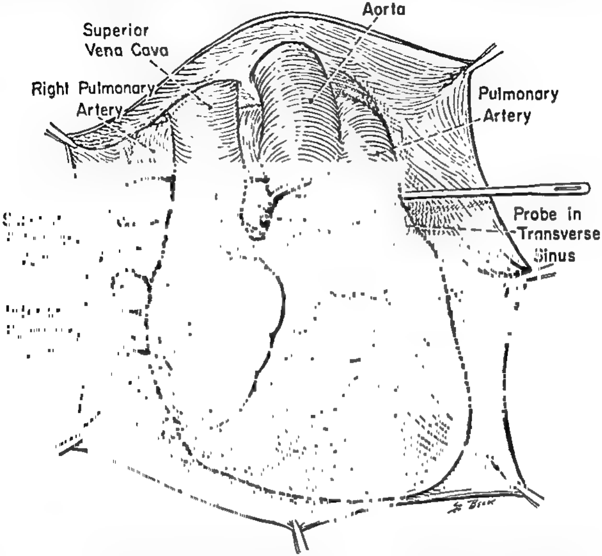


Fig 7-22 The intrapericardial anatomy of the right heart This is a semidiagrammatic illustration of the arrangement of the right pulmonary artery and right superior and inferior veins within the pericardial sac. The reports of Allison (11) and Healey and Gibbon (12) have emphasized the necessity for pericardial exposure of these structures in resection of hilar masses which might otherwise be inoperable The complete knowledge of the intrahilar anatomy both on the right and on the left may serve very well in the control of otherwise uncontrollable hemorrhage from inadvertent injury to a major vessel The reflections of the pericardium on to the vessels which enter it must always be kept in mind.

Arteries to the Right Upper Lobe. Usually three segmental arteries can be identified in the right upper lobe; the apical, the anterior, and the posterior. As Figure 7-23 clearly shows, the superior pulmonary trunk is the main supply to the right upper lobe. It is the first branch of the right pulmonary artery and has a common stem which divides into two branches to supply the apical and anterior bronchopulmonary segments. The arteries enter the lung in front of the right bronchus at the level of the origin of the upper lobe bronchus. At its origin, the superior pulmonary trunk lies behind the superior vena cava and in front it is covered by the visceral pleura The common stem of the apical and anterior stem arteries divides

once when it enters the lobe. It is distributed to the apical segment and to the greater part of the anterior segment. It is the exception to find that these two segmental arteries are the sole supply for the upper lobe. It occurs in less than 10 per cent of the cases, according to Appleton. The third segmental artery supplies the posterior segment. This artery, which is an ascending one, rises from the inferior trunk in the interlobar portion of the right pulmonary artery. This branch is also referred to as the posterior ascending artery or posterior segmental artery.

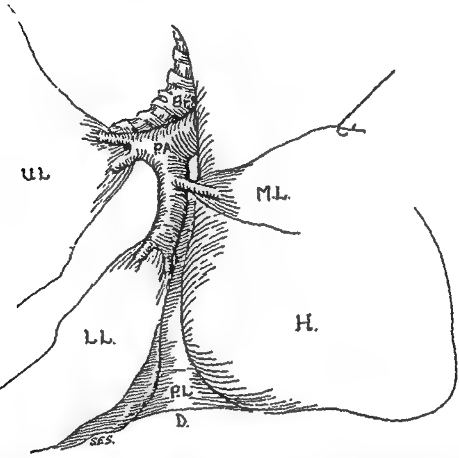
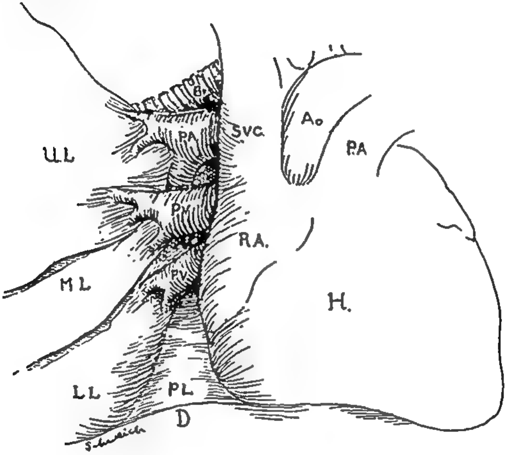


Fig. 7-23 Diagrammatic illustration of the distribution of the right pulmonary artery; the middle lobe has been retracted anteromedially and there is a single arterial division to the middle lobe in this instance. Br., right main bronchus; U.L., upper lobe; M.L., middle lobe; L.L., lower lobe, P.A., right pulmonary artery, P.L., inferior pulmonary ligament, D., diaphragm; H., heart. The veins have not been included so that clarity may be increased. (From Kent, and Blades. J. Thoracic Surg., 12:24, 1942.)

Inferior Pulmonary Trunk (Arteries to the Lower, Middle and Upper Lobes). The inferior pulmonary trunk constitutes the inferior division of the pulmonary artery and supplies the middle and lower lobes and in addition gives off branches to the upper lobe as indicated above. The inferior pulmonary trunk is found anteriorly in the root of the lung. This artery lies below the upper trunk of the pulmonary artery and runs downward and laterally into the interlobar fissure between the upper lobe bronchus and the main lobe bronchus. In the anterior pulmonary hilum, the artery is crossed in front by the superior pulmonary vein (Fig. 7-24), and the apical-anterior segmental vein. Only a small portion of the artery is above the vein and at that level the artery lies beneath the pleura. The

artery lies anterior to the intermediate bronchus. The posterior and inferior veins of the upper lobe separate the artery from the anterior segmental bronchus of the upper lobe. The artery is at first anterior to the bronchus, but upon entering the lung and descending toward the lower lobe, it comes to occupy an anterolateral position in relation to the bronchus. This artery in the depth of the fissure, lies beneath the pleura immediately behind the junction of the oblique and horizontal fissures.



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Arteries to the Middle Lobe. The arteries to the middle lobe arise from the interlobar portion of the pulmonary artery and from its anterior aspect. Usually they are found two in number, one to each bronchpulmonary segment, medial and lateral. Sometimes the artery in the middle lobe can be seen to originate from a common trunk which divides frequently into two or three major branches. In these instances very frequently a smaller accessory middle lobe artery is found supplying the medial bronchopulmonary segment. The arteries to the middle lobe, deep in the interlobar fissure, lie posterior to the corresponding bronchi and slightly above them The medial segmental artery supplies the mediastinal surface of the lobe and the part of the lobe adjacent to the medial interlobar surface.

Arteries to the Right Lower Lobe. The arteries to the right lower lobe follow the corresponding bronchi more closely than those of the

once when it enters the lobe. It is distributed to the apical segment and to the greater part of the anterior segment. It is the exception to find that these two segmental arteries are the sole supply for the upper lobe. It occurs in less than 10 per cent of the cases, according to Appleton. The third segmental artery supplies the posterior segment. This artery, which is an ascending one, rises from the inferior trunk in the interlobar portion of the right pulmonary artery. This branch is also referred to as the posterior ascending artery or posterior segmental artery.

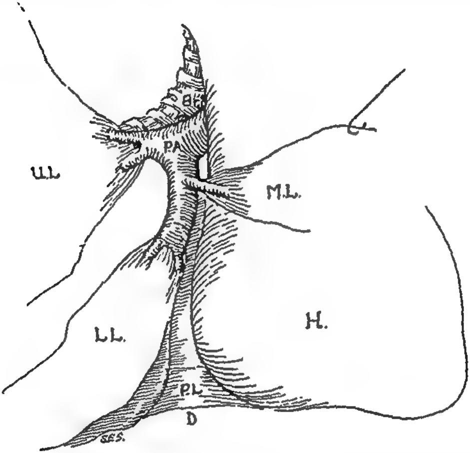

Fig 7-23 Diagrammatic illustration of the distribution of the right pulmonary artery, the middle lobe has been retracted anteromedially and there is a single arterial division to the middle lobe in this instance Br, right main bronchus, U L, upper lobe, M.L., middle lobe, L.L, lower lobe, P.A., right pulmonary artery, P.L, inferior pulmonary ligament, D., diaphragm, H, heart. The veins have not been included so that clarity may be increased. (From Kent, and Blades J. Thoracic Surg, 12 24, 1942)

Inferior Pulmonary Trunk (Arteries to the Lower, Middle and Upper Lobes). The inferior pulmonary trunk constitutes the inferior division of the pulmonary artery and supplies the middle and lower lobes and in addition gives off branches to the upper lobe as indicated above. The inferior pulmonary trunk is found anteriorly in the root of the lung. This artery lies below the upper trunk of the pulmonary artery and runs downward and laterally into the interlobar fissure between the upper lobe bronchus and the main lobe bronchus In the anterior pulmonary hilum, the artery is crossed in front by the superior pulmonary vein (Fig. 7-24), and the apical-anterior segmental vein Only a small portion of the artery is above the vein and at that level the artery lies beneath the pleura. The

artery lies anterior to the intermediate bronchus. The posterior and inferior veins of the upper lobe separate the artery from the anterior segmental bronchus of the upper lobe. The artery is at first anterior to the bronchus, but upon entering the lung and descending toward the lower lobe, it comes to occupy an anterolateral position in relation to the bronchus. This artery in the depth of the fissure, lies beneath the pleura immediately behind the junction of the oblique and horizontal fissures.

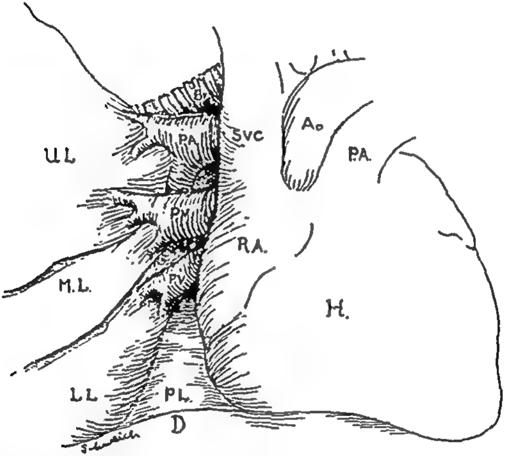

Fig 7-24. Diagrammatic illustration of the anterior view of the right pulmonary hilum
U.L., upper lobe [illegible]
veins, P L., infer [illegible]
P.A , pulmonary [illegible]
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Arteries to the Middle Lobe. The arteries to the middle lobe arise from the interlobar portion of the pulmonary artery and from its anterior aspect. Usually they are found two in number, one to each bronchpulmonary segment, medial and lateral. Sometimes the artery in the middle lobe can be seen to originate from a common trunk which divides frequently into two or three major branches. In these instances very frequently a smaller accessory middle lobe artery is found supplying the medial bronchopulmonary segment. The arteries to the middle lobe, deep in the interlobar fissure, lie posterior to the corresponding bronchi and slightly above them. The medial segmental artery supplies the mediastinal surface of the lobe and the part of the lobe adjacent to the medial interlobar surface.

Arteries to the Right Lower Lobe. The arteries to the right lower lobe follow the corresponding bronchi more closely than those of the

upper and middle lobes and almost duplicate the bronchial pattern. Branches to the superior segment and basal segmental arteries all originate in the inferior pulmonary trunk, some in the interlobar portion of the pulmonary artery, deep in the fissure and some almost within the lung substance. The first branch arising below or at the level of the middle lobe artery, but from the posterolateral aspect of the interlobar portion of the main pulmonary artery, is the superior segmental artery. Anomalous vessels may rise from the superior segmental branch to supply either the posterior portion of the upper lobe or in a paravertebral direction downward.

The arteries to the basal segments arise from the inferior pulmonary trunk, either in the depth of the interlobar fissure immediately below the arteries to the superior segment and to the middle lobe, or from the inferior portion of the pulmonary artery within the lobe itself. The inferior portion of the pulmonary artery lies anterolaterally to the bronchus in the lobar hilum and the various segmental arterial branches follow the corresponding bronchi very closely. Usually four segmental arteries are recognized. Sometimes the pulmonary artery almost within the lobe may divide into two trunks, anterior and posterior. These in turn immediately subdivide into smaller branches to supply the four bronchopulmonary segments.

Left Pulmonary Artery. The left pulmonary artery, from its origin until it gives off the first arterial branch to the left upper lobe, curves in a posterolateral and slightly upward direction. The artery lies above the left bronchus and the superior pulmonary vein. It lies inferior to the aortic arch and vagus nerve (Fig. 7-25). Anterolaterally the artery is covered by the mediastinal pleura and is crossed over by the apical-posterior segmental vein. Posteromedially the artery crosses the main bronchus in a posterior and upward direction. The artery ascends over the superior surface of the main bronchus, arching over the left upper lobe bronchus and then enters the interlobar fissure. In contrast to the right side where the artery is anterior to the bronchus, on the left side the artery passes around and behind the upper lobe bronchus. The arrangement of the structures in the upper lobe hilum in both anteroposterior and inferosuperior directions are vein, bronchus, artery.

Arteries to the Left Upper Lobe. The apical posterior segmental artery arises from the superior or convex surface of the pulmonary artery. It has a common trunk that is very short, almost sessile, and soon divides into two branches: the ascending or apical and the posterior segmental artery. These two branches sometimes originate independently as is illustrated in Figure 7-31 depicting segmental resection of the apical posterior segment of the left upper lobe. The anterior segmental artery arises in the interlobar portion of the pulmonary artery as a branch of the anterolingular arterial trunk or independently from the main artery. The lingular artery arises in the interlobar fissure below or at the level of origin of the superior segmental artery to the lower lobe. In Figure 7-25 it must be realized that the illustrated view is of the posterior surface of the left pulmonary artery. When the artery is exposed in the interlobar fissure, the origin of the lingular artery at the level of the superior segmental artery to the lower lobe will be apparent. The common arterial trunk for the lingula divides into two branches for the superior and inferior bronchopulmonary segments. Occa-

sionally they are seen arising as independent branches. They may also originate from a common trunk with the anterior segmental artery.

ARTERIES TO THE LEFT LOWER LOBE. All the arterial branches to the lower lobe arise from the interlobar portion of the pulmonary artery. The highest arterial branch of the lower lobe is the artery to the superior segment. The superior segmental artery lies in the lobar hilum anterior and superior to the corresponding bronchus. It soon branches into two smaller arteries for the subdivisions of the segment. The arteries to the various basal segments lie anterolaterally to the bronchi in the hilum and follow these very closely into the lung substance. There are usually four arterial branches for the basal segment: anterior, medial, lateral, and posterobasal.

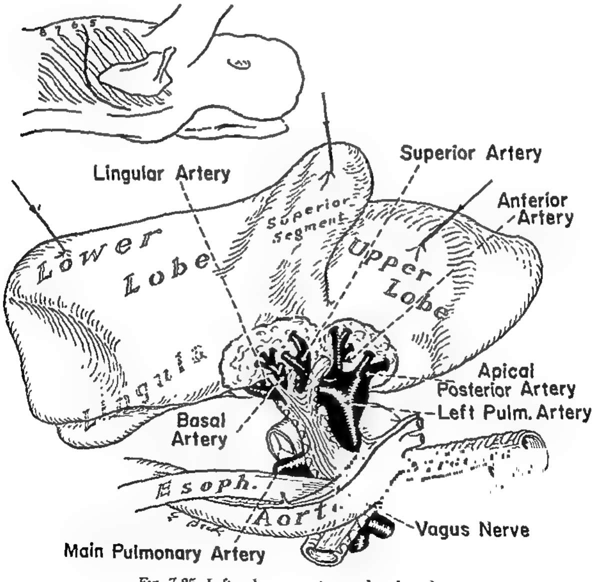

Fig. 7-25 Left pulmonary artery and its branches.

THE PULMONARY VEINS

The veins course peripherally beneath the pleural surface and those which are deep within the lung substance follow the intersegmental plane. Anomalies in the various contributory branches to the main pulmonary vein, superior and inferior, are much more frequently seen than anomalies

of the artery. Communicating veins cross adjacent portions of the lobes when the fissures are incomplete. Even in the presence of complete fissures, veins can be found to cross from one lobe to another. In performing a segmental resection or in separating fused lobes, communicating intersegmental and interlobar veins will require ligation.

Right Pulmonary Vein. The branches of this vein are illustrated in Figure 7-26.

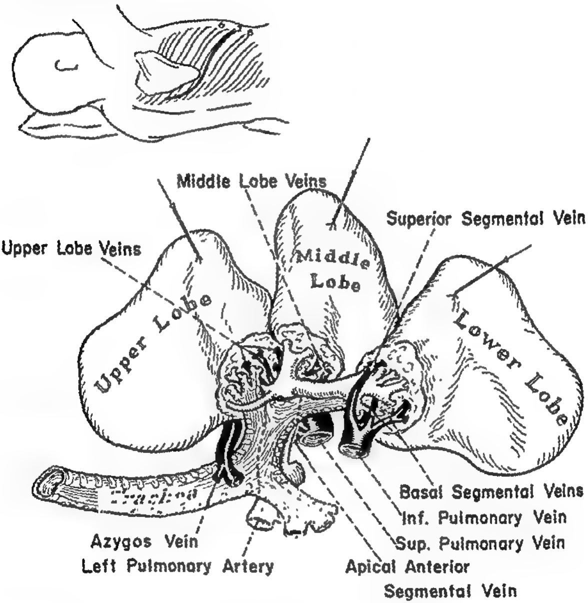

Fig 7-26 Right pulmonary vein and its branches.

Right Superior Pulmonary Vein. The right superior pulmonary vein is formed by all the tributaries from the upper and middle lobe veins as in Figure 7-26. In the hilum of the lung, the superior pulmonary vein lies in front of the inferior trunk of the pulmonary artery and on entering the pericardium, the vein is almost entirely below the right main pulmonary artery. This is somewhat diagrammatically shown in Figure 7-22 depicting the intrapericardial anatomy of the major vascular channels. The three main tributaries which can readily be dissected are: first, the apical-anterior which is mostly superficial beneath the pleura and receives tributaries from the

apical and anterior segment. In the hilum its two main tributaries can be seen coursing down from their corresponding segment. The apical-anterior vein in its descending course crosses over the anterior segmental artery which lies behind and then reaches the superior pulmonary vein at its lateral and superior margin. The second or inferior vein runs along the inferior margin of the upper lobe. It is a superficial vein and is found in the interlobar surface between the upper and middle lobe. The third, the posterior vein, emerges from within the lung substance where it is deeply situated and in the hilum courses in a posterior position to the arteries and bronchi of the upper lobe. At the hilum the posterior vein is concealed by the apical-anterior segmental vein at the line of reflection of the pleura.

VEINS OF THE MIDDLE LOBE. The veins of the middle lobe are two in number, the medial and lateral, and drain their corresponding bronchopulmonary segment. They reach the superior pulmonary vein as a single trunk or separately at its lower margin.

VEINS OF THE RIGHT LOWER LOBE. The inferior pulmonary vein is situated below the superior vein and is slightly posterior to it, as illustrated. The inferior pulmonary vein cannot be seen easily in the anterior hilum because it is partially concealed by the inferior lobe. The inferior pulmonary vein is formed by all the segmental tributaries from the lower lobe. It is found as the inferior pulmonary ligament is carefully dissected. Because of its posterior location, it is more readily isolated as the single trunk on the posterior surface of the lung. As the lower lobe is reflected upward, it is readily brought into view.

The Left Pulmonary Vein. As on the right side, the left pulmonary vein lies in the hilum anterior and inferior to the artery (Fig. 7-27). As the lower lobe is reflected upward, this vein receives all the tributaries from the left upper lobe. These tributaries are all superficial at the hilum, in contrast to the right side, whereas we have already seen that there is a posterior branch, which is quite important. Three or four trunks enter the pulmonary vein and at the hilum they can be found anterior and inferior to the corresponding bronchi. These superficial and anterior trunks bring blood from the anterior mediastinal surfaces of their segments. Central and posterior portions of the segments are drained by veins which run in the intersegmental plans, and are tributaries to the anterior trunks. An apical posterior vein collects blood from the segment of the same name, and this vein is formed by two branches, apical and posterior which join the superior pulmonary vein as a single trunk at the level of the superior and lateral margin of the vein. During its descending course the apical posterior vein crosses the posterior artery which lies behind. In the hilum, this vein lies in front of and below the corresponding segmental bronchus. The anterior vein drains the anterior segment. It is formed by two tributaries, the anterior and posterior, which join before entering the superior pulmonary vein below the apical posterior vein. The lingular veins, superior and inferior, join a superior pulmonary vein separately or as a single trunk. They collect blood from their respective segments and enter the superior pulmonary vein at its lower portion. The inferior lingular vein is occasionally found to be tributary to the superior pulmonary vein. In the hilum the lingular veins lie anterior and inferior to the bronchus.

LEFT INFERIOR PULMONARY VEIN. The left inferior pulmonary vein is formed by all tributaries from the lower lobe except as has been pointed out when a small lingular vein may empty into it. The inferior pulmonary vein lies on the anterior surface of the upper end of the pulmonary ligament, inferior to the superior pulmonary vein and slightly posterior to it. As on the right side, this vein is concealed by the lobe, but to a lesser extent, and its branches should be considered as two groups: those of the superior segment, and those of the basal segment.

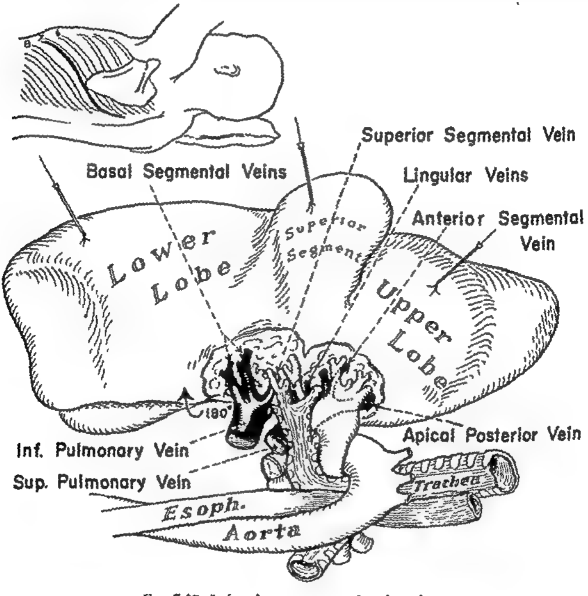

Fig. 7-27. Left pulmonary vein and its branches.

THE BRONCHIAL ARTERIES AND VEINS

The blood conveyed to the lungs by the bronchial arteries is collected and returned largely by the pulmonary vein. Only a small amount of blood is returned by bronchial veins which enter the azygos vein on the right and hemiazygos vein on the left. The bronchial arteries enter the root of the lung slightly below the main stem bronchi on each side. Branches of the artery frequently accompany the larger rami of the vagus as they enter the lung root. The main bronchial artery courses downward and laterally

in the subcarinal areolar tissue in the beginning and does not come in contact with the wall of the bronchus on either side until it has reached the level of the first division of each major bronchus. The bronchial vessels in the presence of inflammatory disease of long standing may be much increased in size.

SPECIFIC RESECTIONS OF THE LUNG

With the surgical anatomy of the bronchovascular segments reviewed, the technic of specific resections is now considered. The thorax may be approached through an anterior incision as illustrated in Figure 7-28. With

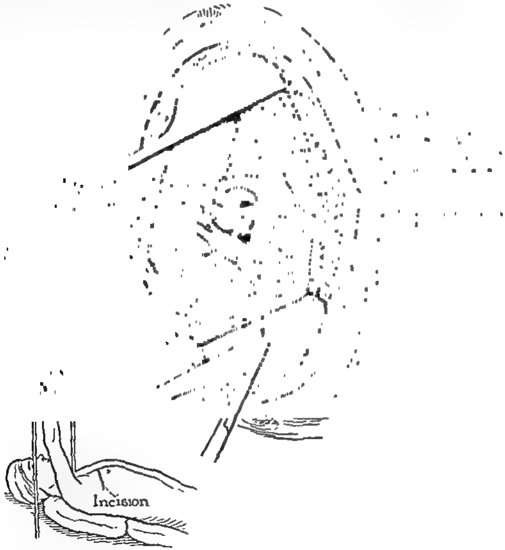

Fig 7-28 Diagrammatic illustration of the anatomy of the hilum of the right lung as viewed through the anterior approach. The inset shows the position of the patient on the table with the incision made lateral from the sternum in the right third interspace. After the mediastinal pleura is divided lateral to the phrenic nerve, and dissected free, the hilar vessels may be developed so as to be found to occupy the relative positions as indicated. Division of the azygos and superior pulmonary veins gives more ready access to the pulmonary artery and right main bronchus, accurate visualization of which is very important

the patient in this position, no rib resection is necessary. There is no respiratory embarrassment, the muscles are split, not cut, and the incision may be closed more quickly. However, closure is not quite so tight as in

the posterolateral approach. Furthermore, the posterior aspect of the hilum is more difficult, and the separation of adhesions to the chest wall and diaphragm is less easily accomplished.

The prone or face down position as advocated by Overholt and Langer(13) has the advantages of allowing for more favorable drainage of bronchial secretion, and not interfering with the excursion of the chest wall and diaphragm on the nonoperative side. There is little need for traction since the lung naturally falls forward and for this reason the posterior hilum structures are readily accessible. If hemorrhage occurs, it flows away from its source leaving the hilum visible, making control of hemorrhage easier. Despite the many advantages of this position, the third or posterolateral incision of the thorax which has been illustrated is most commonly employed.

Right Pneumonectomy. Positioning of the patient is most important. The thorax should be properly supported and the level of the table adjusted to facilitate the operator's movements. Adequate sized needles should be placed securely in veins for the administration of supportive fluids. The arm on the side to be operated should be relatively free so that the muscle groups can be made to approximate each other in closure. Because of the length of time needed to accomplish surgical procedures all pressure points should be carefully padded. When possible, the administration of fluid by arm vein is preferable to prevent the possibility of postoperative thrombophlebitis in leg veins.

The fifth or sixth ribs may be selected for resection from posterior to their angles to the costal cartilages anteriorly. The separation of adhesions when necessary is carried out as expeditiously as possible The importance of adhesions varies considerably depending upon whether the resection is for tumor, tuberculosis, or nonspecific inflammatory processes.

The mediastinal pleura is divided medially to the phrenic nerve and its accompanying vessels The phrenic nerve may be retracted out of harms way by the placement of a silk traction ligature which may remain untied for the time being. The loose areolar tissue about the vessels of the hilum is gently dissected away from these vessels and the first step in adequate exposure of the region is the clamping, division, and tying of the azygos vein. The vagal branches to the posterior pulmonary plexus are dissected out and ligated The posterior aspect of the pulmonary hilum may be freed under direct vision and the posterior reflection of the pleura from the chest wall carefully divided. The right main bronchus will be readily visible. The dissection of the superior pulmonary vein with distal ligation of its branches and proximal ligation of the main trunk which in turn is further secured by separate transfixion ligature before division will facilitate exposure of the pulmonary artery As the various illustrations indicate the right pulmonary artery may be ligated intrapericardially if necessary for either the emergency control of hemorrhage distally or because of the necessity of removal of further tissue due to tumor involvement The same is true for the pulmonary veins When feasible, blunt finger dissection aided by careful use of a Mixter type forceps will circumferentially free the right pulmonary arterial trunk extrapericardially. It is important that the posterior wall of the artery be freed to a sufficient extent to allow for the placement

of a separate transfixion ligature, distally. The peripheral ligatures may be placed on the branches of the artery to the upper lobe. Division of the artery is then carried out. The pulmonary ligament may then be divided carefully up to the point of the lowermost branch of the inferior pulmonary vein. Division of the posterior and anterior layers of mediastinal pleura, and reflection of lower lobe upward will produce satisfactory visualization of the inferior pulmonary vein. The posterior aspect of this vein will allow for better visualization. Proximally it may be tied as a single trunk and a second separate transfixion ligature similarly placed. Distally, its branches may be separately tied and careful division of the tissue between accomplished. The remaining step is the dissection and division of the main bronchus. Bronchial arteries may be separately identified, clamped, divided, and tied. After dissection has cleared the main bronchus, traction sutures may be placed and division of the bronchus begun in the manner described by Sweet(14). The distally placed clamp allows for control of the lung and as transection is accomplished, immediate closure of the open bronchus with interrupted silk sutures is carried out (Fig. 7-29). After complete transec-

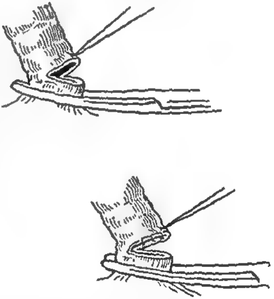

Fig 7-29 Illustration of the method of closure of a main bronchus as described by Richard Sweet. The clamp is placed distally. As the bronchus is severed, the portion opened is closed by a fine silk suture. This is repeated until the bronchus is completely cut across and completely closed by multiple sutures Not illustrated are the bronchial arteries which may be controlled by these sutures or may have to be separately ligated. Note that there is no trauma to the proximal segment. The final step in closure is pleuralization of the sutured end This is the major factor in secure healing.

tion, the lung is removed from the operative field and the careful closure of the bronchus completed. It may be necessary to divide the bronchus at a higher level. It is important to aspirate from the bronchus as it is being closed, any secretion, clots, or pieces of tumor which may have become detached and which may produce respiratory obstruction if they are not removed. All bleeding points are secured and the anesthesiologist instructed to apply positive pressure to the closed bronchus. Physiologic saline solution placed in the pleural space will help detect any leakage of air from an incompletely closed bronchus. When the surgeon is satisfied that the bronchial closure is airtight, adjacent pleura may be used to pleuralize the bronchial stump. This is the greatest assurance to firm bronchial closure through protective healing.

It is possible through adequate exposure to remove the lung and do a block dissection of the mediastinal lymph nodes. This is imperative in pneumonectomy for cancer. In all pulmonary resections, careful protection

the posterolateral approach. Furthermore, the posterior aspect of the hilum is more difficult, and the separation of adhesions to the chest wall and diaphragm is less easily accomplished.

The prone or face down position as advocated by Overholt and Langer(13) has the advantages of allowing for more favorable drainage of bronchial secretion, and not interfering with the excursion of the chest wall and diaphragm on the nonoperative side. There is little need for traction since the lung naturally falls forward and for this reason the posterior hilum structures are readily accessible. If hemorrhage occurs, it flows away from its source leaving the hilum visible, making control of hemorrhage easier. Despite the many advantages of this position, the third or posterolateral incision of the thorax which has been illustrated is most commonly employed.

Right Pneumonectomy. Positioning of the patient is most important. The thorax should be properly supported and the level of the table adjusted to facilitate the operator's movements. Adequate sized needles should be placed securely in veins for the administration of supportive fluids. The arm on the side to be operated should be relatively free so that the muscle groups can be made to approximate each other in closure. Because of the length of time needed to accomplish surgical procedures all pressure points should be carefully padded. When possible, the administration of fluid by arm vein is preferable to prevent the possibility of postoperative thrombophlebitis in leg veins.

The fifth or sixth ribs may be selected for resection from posterior to their angles to the costal cartilages anteriorly. The separation of adhesions when necessary is carried out as expeditiously as possible. The importance of adhesions varies considerably depending upon whether the resection is for tumor, tuberculosis, or nonspecific inflammatory processes.

The mediastinal pleura is divided medially to the phrenic nerve and its accompanying vessels. The phrenic nerve may be retracted out of harms way by the placement of a silk traction ligature which may remain untied for the time being. The loose areolar tissue about the vessels of the hilum is gently dissected away from these vessels and the first step in adequate exposure of the region is the clamping, division, and tying of the azygos vein. The vagal branches to the posterior pulmonary plexus are dissected out and ligated The posterior aspect of the pulmonary hilum may be freed under direct vision and the posterior reflection of the pleura from the chest wall carefully divided. The right main bronchus will be readily visible. The dissection of the superior pulmonary vein with distal ligation of its branches and proximal ligation of the main trunk which in turn is further secured by separate transfixion ligature before division will facilitate exposure of the pulmonary artery. As the various illustrations indicate the right pulmonary artery may be ligated intrapericardially if necessary for either the emergency control of hemorrhage distally or because of the necessity of removal of further tissue due to tumor involvement. The same is true for the pulmonary veins. When feasible, blunt finger dissection aided by careful use of a Mixter type forceps will circumferentially free the right pulmonary arterial trunk extrapericardially. It is important that the posterior wall of the artery be freed to a sufficient extent to allow for the placement

be performed for tumor when that tumor is benign or for malignant tumor when there is a single metastasis or when respiratory insufficiency demands the preservation of lung tissue as lifesaving in itself.

Because infection is the usual indication, a posterolateral incision is employed in order to allow for the most effective type of drainage postoperatively. As was discussed under Pneumonectomy, the chest wall is opened by an incision at the level of the fifth to seventh ribs, depending on the lobe to be removed, extending from just before the spine, curved below the angle of the scapula to the anterolateral chest wall. It is customary to remove a rib over this length and to divide the posterior periosteum to gain access to the pleural space. Ribs above or below may also be divided. In young subjects an intercostal incision will suffice.

A. TOURNIQUET LOBECTOMY.

Until individual ligation technic for the removal of a pulmonary lobe was developed, tourniquet lobectomy was the method of choice. At present it is resorted to only when the individual ligation technic is impossible or too hazardous, or, in the removal of the right middle lobe. The lobe to be removed is separated and its hilum developed to the greatest possible extent. Either a Shenstone or Bethune type of tourniquet is then placed, one proximally and the other distally, as illustrated in Figure 7-30. Large transfixion sutures of chromic catgut are placed in the tissues between the tourniquets so as to prevent it from slipping within the proximal tourniquet after division has taken place. Division is then accomplished and the individual vessels of the stump are each carefully secured. The tourniquet is then loosened but maintained in place and additional bleeding or open bronchi, if present, are also carefully closed. The lung has been removed so a cuff of pleura may be closed over it. The incision in the chest wall is then closed, using catheter drainage with the two-bottle arrangement as has been described in Figure 7-7.

It is obvious that the gross removal of tissue does not allow for high division of infected bronchi which is a distinct disadvantage in the treatment of bronchiectasis.

B. INDIVIDUAL LIGATION TECHNIC.

1. Right Upper Lobectomy. The structures which require resection and division are: a, the superior pulmonary arterial trunk with branches to the apical and anterior segments; b, the posterior ascending artery, a branch of the inferior pulmonary trunk; c, the tributaries to the superior pulmonary vein, and d, the apical, anterior, and posterior segmental bronchi.

Mobilization is begun by division of the mediastinal pleura of the right upper lobe. The azygos vein is the landmark through which the right upper lobe pulmonary artery is identified. The arterial branches are dissected out separately and ligated peripherally. Proximally a mass ligature is placed on the common stem for the two arterial branches and this is reinforced by a transfixion ligature slightly more distally. After division of the pulmonary artery the superior pulmonary vein branches to the upper lobe are similarily handled. It may be that these may be more readily cared for as a primary step. The branches to the middle lobe should be carefully preserved. The

of the pleural space is provided, particularly at the point where the bronchus has been divided, to prevent contamination by infected bronchial secretion. So as to facilitate obliteration of the pleural space after removal of the lung, the phrenic nerve is divided between ligatures and the thorax closed without drainage. An antibiotic of the operator's choice in sufficient quantity may be left within the pleural space. The pressure within the pleural space should be measured by a manometer and left slightly on the negative side as the external dressing is applied. The dressing need not be voluminous.

Left Pneumonectomy. The structures of the left hilum which require dissection are the same as on the right except that there is no azygos vein. All the posterior vagal branches to the pulmonary plexus are ligated and divided. The mediastinal pleura is incised from below the arch of the aorta to the inferior pulmonary vein and the phrenic nerve protected from injury by a traction silk suture. Careful dissection of the areolar tissue will disclose that proximal ligature with a second transfixion type suture and division between these and ligatures placed upon the branches of the superior pulmonary vein will allow for division of this structure and more adequate exposure of the left pulmonary artery. The artery runs beneath the aortic arch. It is anterior and superior to the main bronchus. After the upper lobe has been mobilized, the subclavian artery, the vagus and phrenic nerves come into view. The intrapleural portion of the main pulmonary artery is short. It is safer and more expedient, therefore, to dissect the common trunk to the posterior apical segment and on its branches place in such a manner two distal ligatures. By blunt and finger dissection, the areolar mediastinal tissue surrounding the artery is freed and the proximal ligature placed. The proximal ligature should be further supported by a slightly distal transfixion type of suture. Division of the peripheral attachments of the lung, including the inferior pulmonary ligament, will allow for visualization of the inferior pulmonary vein. This is managed as described in right pneumonectomy. Sometimes it is more feasible to secure the inferior pulmonary vein before the superior pulmonary vein has been ligated. In these instances, it will first be necessary to take care of the pulmonary artery, then the inferior pulmonary vein, and by reflection of the lung upward the exposure of the superior pulmonary vein is made more easy. The lung is then attached only by the bronchus. The bronchus is longer than on the right, facilitating all the maneuvers for its isolation and treatment. The bronchial artery if easily identified, should be ligated separately. The chest is closed without drainage as described under right pneumonectomy.

No. 1 silk is preferred in the ligation and transfixion ligation of the main pulmonary vascular division. The smaller vascular components can be securely held with No. 0 or No. 00 silk. Using the method of Sweet to close the bronchus, the posterior membranous portion is approximated through the cartilaginous ring with either No. 00 or No. 000 fine silk placed on a cutting needle in long strands. A cutting needle is advantageous in that it can be pushed through the cartilaginous bronchus without undue pressure or effort.

Lobectomy. Lobectomy is ordinarily indicated in pulmonary infections such as bronchiectasis, lung abcess, suppurative pneumonitis, and in more recent years tuberculous processes as dictated by established criteria. It may

The pleural space is protected from contamination as the bronchus is divided. Intratracheal positive pressure will determine the success of the bronchial closure. In the case of incomplete fissure reexpansion of the lung to remain will allow for the employment of the principle used in segmental resection of separation of adjacent lung sections. The chest wall is closed after the introduction of anteriorly and posteriorly placed Pezzar catheters which are connected with a Y tube and thence to a negative pressure apparatus to encourage early and complete reexpansion of the remaining lung to fill the pleural space and prevent the development of fluid accumulation and therefore postoperative empyema. These catheters are left in place until a postoperative roentgenogram of the chest discloses that adequate expansion has taken place and drainage has ceased.

2. Middle Lobectomy. The structures of the secondary hilum which are encountered and managed are one or two middle lobe arteries which arise from the inferior pulmonary trunk, the lobar bronchus, with a short common trunk or two segmental divisions, and the middle lobe vein or veins, tributary to the superior pulmonary vein. These bronchovascular structures to the middle lobe can be approached through the interlobar fissure. The hilar portion of the oblique fissure is developed. The fissure between lower and middle lobes is almost always well demarcated. At that level the artery can be seen giving off divergent arterial branches for the lower and middle lobes. The middle lobe artery or arteries have a downward and forward course. They arise opposite the superior segmental artery as has been pointed out. The divisions of the middle lobe artery should be carefully dissected before they are proximally tied. Occasionally it is from these arteries that the sole source of blood supply to the posterior bronchopulmonary segment of the upper lobe will be forthcoming and should therefore be avoided in the ligature. The middle lobe bronchus appears as it lies anterior and slightly inferior to the artery. The lobar bronchus may be ligated as a single trunk or at the level of the segmental division or if there are two bronchi to the middle lobe arising separately they are so treated. An Allis forceps is placed so as to exert traction on the distal bronchus. The middle lobe vein comes into view after the mediastinal pleura has been divided below and on the anterior surface of the middle lobe hilum. Care should be taken to dissect in this area with caution. The principal trunk of the superior vein must not be injured. In the event of an undeveloped fissure, no attempt should be made to find and ligate the communicating veins between the middle and upper lobes until later in the dissection. It is again pointed out that management of the bronchi to the middle and upper lobes must be accomplished without interference to the bronchial channel to the lower lobe which may give off its division to the superior segment of that lobe at the same level. The final step is the dissection of the minor fissure and an undeveloped fissure is more frequently found than not. The middle lobe is separated from the upper lobe by a method similar to that used in removing segments. Traction forceps are placed on the peripheral ends of the severed bronchus, artery and vein and with the remaining lobes inflated for purpose of demarcation, slight traction is made. Gentle, blunt dissection with the thumb and forefinger separates the lung tissue to be removed from that which remains. A small sponge forceps or wiper may be employed.

portion of the oblique fissure between the upper and lower lobes should be developed in order to expose the posterior ascending segmental artery. This structure is variable in size and in origin and may be crossed by anomalous veins. The dissection of the posterior segmental artery is one of the most important steps and sometimes the most difficult operative procedure in the performance of right upper lobectomy. It has been found that in cases where the oblique and horizontal fissures are fused or incompletely developed, section of the posterior artery is more safely done in a retrograde manner.

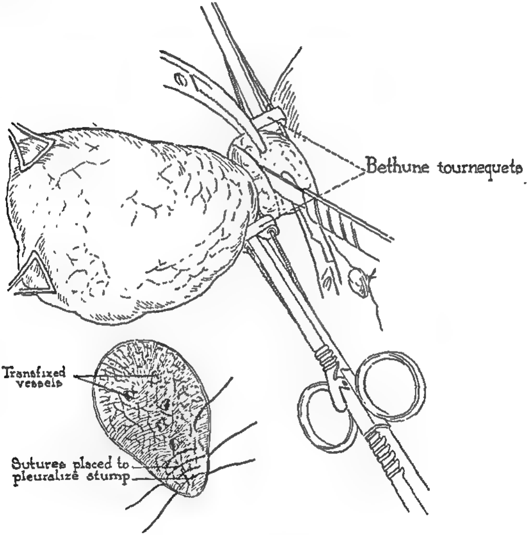

Fig. 7-30 Tourniquet lobectomy The lobe to be excised has been isolated by development of its fissures, so that the tourniquet can be placed close to the hilum Clamps grasp lung between the tourniquets to prevent the proximal segment from slipping when the lung is divided Pleuralization of the stump is most important to prevent postoperative opening of the bronchi. This procedure is now seldom used It is historically important Tourniquet control of hemorrhage due to injury may sometimes be necessary

The bronchus is by choice sutured at the level of the segmental bronchi. The lobar bronchus may have a short stem and the sutures may encroach upon the main bronchus unless this practice is carried out. Such sutures would produce edema with consequent obstruction to the remaining bronchial channel interfering with the reexpansion of the middle and lower lobes.

tuberculosis, high amputation is important. Removed tuberculous lower lobes have almost invariably shown submucosal infiltration of the disease in the superior segmental bronchus. Therefore, this entire segmental bronchus should be removed. Because it is on the level or above the middle lobe orifice, a transection of the intermediate bronchus is necessary. Thus, if the indication for resection is tuberculosis, the middle lobe should also be included in the excision of the lower lobe(15).

4. Left Upper Lobectomy. The components of the secondary hilum which require dissection are the upper lobe branches of the pulmonary artery, four to seven in number, the superior pulmonary vein and its tributaries, and the upper (apical posterior and anterior), and the lower (lingular) bronchial divisions.

The upper lobe is completely separated from the chest wall attachment. The fissure is then developed in its superior aspect. The upper lobe is retracted and the mediastinal pleura with the pulmonary artery is incised. The apical posterior arteries are the uppermost branches of the pulmonary artery and will be easily identified by exposing the main pulmonary artery and dissecting toward the lobe (Fig. 7-31). They arise from the convex surface of the main trunk slightly anterior to its midpoint. Proximal and distal ligatures are placed on each of the branches. It may be expedient to ligate the apical posterior segmental vein prior to the dissection of the apical posterior arterial branches. The vein anterior to the artery which it crosses before entering into the superior aspect of the main vein.

After the two arterial branches have been ligated, the main pulmonary artery is followed as it courses deep in the fissure. The remaining arterial branches for the upper lobe originate lower down in the main trunk. They arise from the lateral and anterior surface of the main trunk as they course down in an anterior direction. Needless to say the main pulmonary artery as well as the artery to the superior division of the lower lobe should be carefully avoided while the arteries to the upper lobe are being dissected. The course of the artery as it encircles the main bronchus, first above and then posterior, lateral and finally anterior to the lower lobe bronchus, places it in a most vulnerable position. It is well at first to dissect at a safe distance out in the substance of the lung if there is any question about the location of the main pulmonary artery. The injury to the main artery would constitute a grave technical error and might necessitate its ligation and functional loss to the lower lobe. If severe injury forces sacrifice of the main artery, it is preferable to abandon lobectomy and proceed immediately with total removal of the lung.

In order to expose the superior pulmonary vein, the lobe is retracted backward and the mediastinal pleura is incised over it. The dissection is then carried out peripherally toward the lung substance. All the tributaries are isolated and ligated separately. Proximal ligature may be placed on the main stem of the vein or out on the branches, which ever is the most convenient, provided that there is sufficient cuff between the ligatures. Transfixion ligature, proximally, is advocated.

The remaining bronchial structures to the upper lobe should be approached from the posterior surface which allows for the full view of the remaining main pulmonary artery. It is preferable to amputate the bronchus

The intercommunicating veins are delicate and the dissection must be done with a light touch. The few crossing veins are readily clamped with mosquito forceps and ligated. The lobe can then be peeled away with gentle traction after the division of the interlobar connective tissue or fibrous bands and fused visceral pleura. In the event of an incomplete major fissure of fusion resulting from disease, the same method is used as for the minor fissure; that is, the lobes are separated after the hilar structures have been divided.

3. Right Lower Lobectomy. The structures of the secondary hilum which require dissection are: a, the superior and basal segmental arteries; b, branches of the inferior pulmonary vein and its tributaries; and c, the superior and the basal bronchi. The pulmonary artery is accessible deep in the oblique fissure and is usually visible beneath the visceral pleura unless there are enlarged lymph nodes which fill out the crevices between the bronchi and arteries and obscure these structures. The oblique fissure is opened for its entire length and this can be accomplished easily at first. Areas of dense fusion and incomplete formation are avoided and their dissection postponed until after the bronchovascular structures have been divided. The bronchoarterial pedicle of the lower lobe is found deep in the fissure at the level where the minor fissure takes origin. The superior artery is above and anterior to its bronchus and will be found to arise from the posterolateral aspect of the main artery directly opposite the middle lobe artery or arteries. The superior artery should be dissected out peripherally at its branches before its ligation. On rare occasions the posterior ascending artery to the upper lobe may be seen to originate from the superior artery and should be carefully preserved. Dissection of the basal arteries is then continued The basal artery lies anterior and lateral to the basal bronchus. The common stem to the basal artery is short. It is well to expose the four arterial basal branches peripherally and tie them separately or in pairs. Sometimes the medial and the anterior basal arteries have a common stem as do the lateral and posterior basal arteries. This has been pointed out in the previous anatomic description. The medial lobe artery should be partially exposed before ligating the main pulmonary artery to avoid occlusion of the middle lobe artery in the proximal ligature.

After division of the pulmonary ligament, the inferior pulmonary vein is exposed. It is managed, as has been described under right pneumonectomy, by placing a ligature and a transfixion ligature on the main trunk and distal ligatures on the branches of the inferior pulmonary vein. It should be remembered that the inferior trunk of the pulmonary vein is short and is contained in the pericardial reflection (Fig. 7-27).

Once the arteries and veins have been ligated, the bronchi of the lower lobe can be approached either inferiorly, posteriorly, or through the interlobar fissure. The bronchial pattern resembles the arterial distribution of the lobe and is treated the same way as the arteries. The superior segmental bronchus and the basal bronchus should be divided separately. The superior arises at the same level as the middle lobe bronchus. It is, therefore, technically difficult to carry the line of amputation above the origin of the superior segmental bronchus without endangering the orifice of the middle lobe bronchus.

In the performance of right lower lobectomy for basal and bronchial

at the level of the segmental bronchi. If the amputation is carried through the lobar bronchus itself, there is a possibility that the sutures may be placed too close to the main bronchus with the resulting edema and obstruction of the lower lobe bronchus with failure of the lower lobe to expand in the postoperative period.

5. LEFT LOWER LOBECTOMY. The structures of the left lower secondary hilum which require management are: the superior and basal segmental arteries, the branches of the main pulmonary artery, the inferior pulmonary vein and its tributaries, and the superior and basal bronchi.

All the arterial branches to the lower lobe arise from the pulmonary artery deep in the fissure. Development of the midportion of the great fissure and the exposure of the mediastinal surface of the lower lobe constitute the first step in the dissection of the arterial branches to the lobe. As on the right, when dealing with the middle lobe the arteries to the lingula should be identified before the arteries to the lower lobe are isolated. If the common stem artery to the basal segment is long, both the proximal and distal ligatures may be placed about it. It is usually safe to place distal ligatures on the basal branches.

The inferior pulmonary vein is best approached from the posterior aspect of the pulmonary hilum. The lobe is allowed to drop forward, the posterior border of the lobe is retracted laterally and the vein is exposed. The mediastinal pleura over the posterior hilum is incised. The lower lobe veins are seen coming from the lobe, posterior to the bronchus. The superior vein and the basal veins are dissected out and distal ligatures placed about them. The proximal ligature can be placed on the main stem with a somewhat distal transfixion ligature placed to secure the main vessel. The diaphragmatic surface of the lung is freed and the inferior pulmonary ligament is divided.

With the arteries and the veins to the lower lobe already ligated, the bronchi to the lower lobe can be approached either from below, posteriorly, or through the interlobar approach. Again it should be stated that it may be preferable to separately divide the superior segmental bronchus and the basal bronchus.

In some cases it may be technically possible as well as desirable to amputate the lower lobe bronchus above the origin of the superior segmental bronchus. Lobectomy for adenoma or tuberculous cavitation of the lower lobe provides the most frequent indication for high bronchial amputation.

Segmental Resections. As has been previously pointed out, the newer technics based on the knowledge of the detailed anatomy of the pulmonary bronchovascular pattern have led to the resection of the smaller segmental and subsegmental divisions of the lung. It has led to the preservation of functioning lung tissue by the removal of only the segments affected by a given disease process. This disease process may be bronchiectasis which will involve an entire lobe such as the left lower, and the segment of the left upper such as the lingula. It may be a lung abcess localized perhaps to the superior segment of the lower lobe or the anterior or posterior segment of an upper lobe. It may be tuberculosis whose whole existence in the upper lobe and in the superior segment of the lower is well known. It may be a

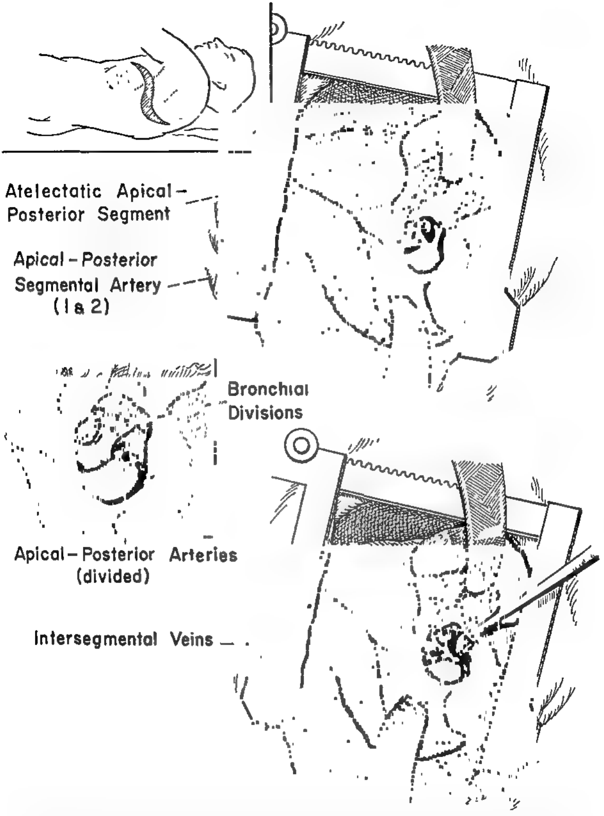

Fig 7-31. This illustrates the removal of the apical posterior segment of the left upper lobe A periscapular incision has been made as indicated in the insert. The Finochietto rib spreader has been placed, and after division of the pleura beneath the arch of the aorta the pulmonary artery is exposed The apical posterior segmental artery appears as two separate branches arising from the convex portion of the pulmonary artery. These are dissected free, carefully tied and divided between ligatures The second insert shows the exposed bronchial division after severing of the segmental arteries The bronchus is divided after proximal ligature, and traction clamps are placed upon the distal end of the divided bronchi and arteries With the remainder of the left upper lobe inflated through application of gentle positive intrabronchial pressure, the atelectatic apical posterior segment is gently finger-dissected away, clamping and tying as may be necessary. Reinflation of the remaining lung tissue is accomplished by insertion of Pezzar catheters attached to a negative pressure apparatus. Drainage of air and fluid will cease after 24 hours, and the catheters may be withdrawn when the postoperative x-ray shows the lung to be expanded

raw surface which remains is not closed. The air leakage is negligible and is self sealing. The prompt healing of the denuded lung surface takes place when tissue is not traumatized, and blood supply not embarrassed.

Specific Resections. As has been stated, segmental resection is merely the application to smaller subdivisions of the principles of resection of the major divisions. Right middle lobectomy corresponds to left lingulectomy which is a segmental resection. Figure 7-32 illustrates the method of retrograde dissection first proposed by Clagett for removal of the lingula without clamps. The lower lobe has been previously resected and the lingula artery has been identified and divided before application of the traction clamp to the bronchus. Figure 7-31 illustrates the removal of the apical posterior segment of the left upper lobe. A periscapular incision has been made as indicated in the insert. The Finochietto rib spreader has been placed, and after division of the pleura beneath the arch of the aorta the pulmonary artery is exposed. The apical posterior segmental artery appears as two separate branches arising from the convex portion of the pulmonary artery. These are dissected free, carefully tied and divided between ligatures. The second insert shows the exposed bronchial division after severing of the segmental arteries. The bronchus is divided after proximal ligature, and traction clamps are placed upon the distal end of the divided bronchi and arteries. With the remainder of the left upper lobe inflated through application of gentle positive intrabronchial pressure, the atelectatic apical posterior segment is gently finger-dissected away, clamping and tying as may be necessary. Reinflation of the remaining lung tissue is accomplished by insertion of Pezzar catheters attached to a negative pressure apparatus. Drainage of air and fluid will cease after 24 hours, and the catheters may be withdrawn when the postoperative x-ray shows the lung to be expanded.

POSTRESECTION MANAGEMENT AND COMPLICATIONS

The three most important points to consider after resection of the lung are:

1. The maintenance of an unobstructed airway;
2. The complete reexpansion of the lung tissue after lobectomy and segmental resection with obliteration of the pleural space; and
3. The avoidance of disturbing shifts of the mediastinum.

Before the patient leaves the operating room, the chest is checked by inspection and auscultation to note any evidence of retraction of the ribs, or absence of breath sounds where breath sounds should be. Before withdrawal of the intratracheal tube, all secretions should be aspirated from the tracheobronchial tree, and their character noted. After the tube has been withdrawn, if it is felt that troublesome secretion remains, then bronchoscopic aspiration may be immediately performed. When the patient returns to the recovery room, provision is made for the catheter aspiration of tracheobronchial secretions. This practice is continued, also, by the resident staff when the patient returns to his room. Oxygen may be given, preferably by nasal catheter, or by oxygen tent. The patient, while in the recovery room, should have a scout x-ray made of the chest so that the position of the mediastinum is noted. When total removal is performed, no drainage is

well circumscribed tuberculoma or a pulmonary cyst, or, perhaps, a solitary metastatic lesion, or a hamartoma, fibroma or chondroma. These lesions can best be removed through excision of the particular segment in which they are located.

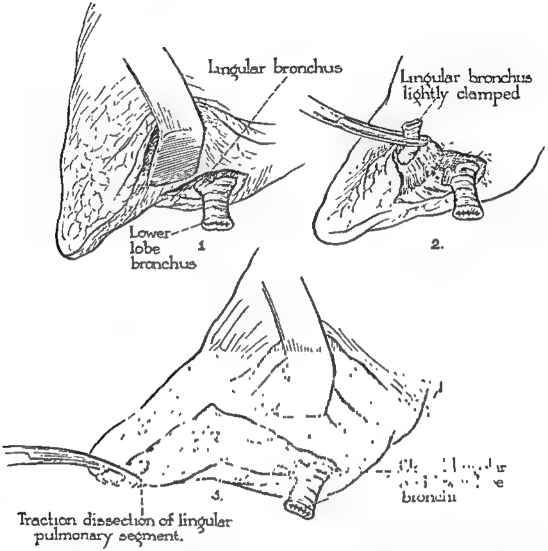

Fig 7-32. Illustration of the manner in which the lingula of the left upper lobe may be removed by segmental resection after resection of the lower lobe. The lingular artery and vein have been severed. Through clamping the lingular bronchus and inflating the remainder of the upper lobe under positive pressure, the demarcation of atelectatic lingula can be made clear so that relative avascular blunt dissection by traction can be accomplished. The raw surface is not closed over.

The unit arrangement of the bronchus, the branch of pulmonary artery and the segmental veins to each lung segment has led to the development of the technic used to accomplish the operation. The retrograde method of Clagett(16) as employed in the removal of the lingula of the left upper lobe without the use of clamps has pointed the way for further refinement and success in segmental resection. The gentle finger and "pledget" dissection of the atelectatic tissue to be removed after division of the segmental artery and traction on the divided distal end of the segmental bronchus with inflation of the remaining pulmonary tissue has been very effective. The few venous branches which cross between segments are ligated. The

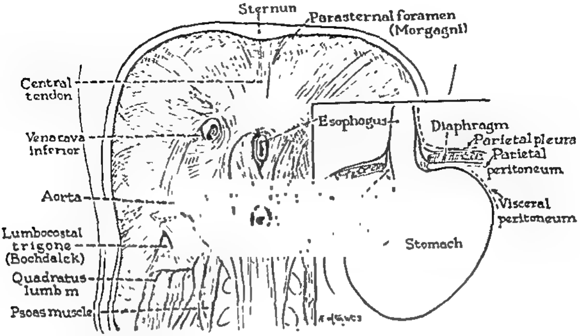

Fig 7-33. The adult diaphragm viewed from below. The most common potential sites of herniation in their order of frequency are the lumbocostal trigones (foramens of Bochdalek), the esophageal hiatus, and the parasternal foramens (Morgagni).

Insert depicts the anatomy of the esophageal hiatus which lies slightly to the left of the midline (usually more than illustrated in the main drawing). From the drawing it is possible to visualize the three layers which constitute the sac of an esophageal hiatus diaphragmatic hernia. This is a sliding type of herniation involving primarily the cardiac end of the stomach. The *innermost layer is made up of parietal peritoneum*. The middle layer is formed by the fascia of the muscle of the diaphragm (continuation of the transversalis) or diaphragmatico-esophageal membrane (Harrington). Parietal pleura makes up the outermost layer.

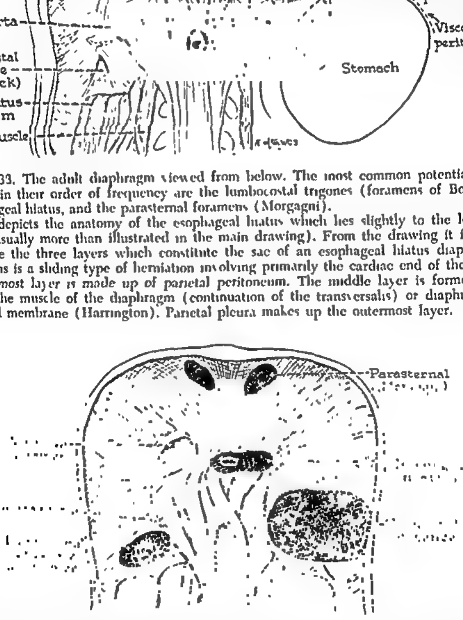

Fig. 7-34 Congenital diaphragmatic hernia The diaphragm viewed from below, depicting the congenital openings through which herniation of abdominal contents may occur

The lumbocostal trigone (Bochdalek) is the most common These hernias do not ordinarily have a sac. The esophageal hiatus type in which herniation into the posterior mediastinum occurs does have a sac which has been described The parasternal (Morgagni) variety usually has a sac in which omentum is most frequently found Their anterior location leads to difficulty in differentiation from anterior mediastinal thoracic tumors The congenital absence, usually of the posterior diaphragmatic leaf obviously presents the most difficult problem of repair. Most of the congenital posteriorly located diaphragmatic hernias are left-sided owing to the presence of the liver on the right preventing exit of the abdominal *contents during the latter stages of the* embryologic development. Colon, small intestine or both ordinarily are the herniated viscera.

employed. When simple exploration, lobectomy, or segmental removal of tissue has occurred, then Pezzar catheter drainage attached to a negative pressure drainage apparatus is set up. The Chaffin pump has proved very satisfactory in our hands. The underwater seal is quite adequate.

The patient is encouraged to lie with the operated side down at regular intervals in the postoperative period. Adequate pain relief for coughing and the spontaneous removal of retained secretion by the patient's own effort is an important consideration. There will be times when adequate sedation, instead of depressing respiration to the patient's detriment, will rest the patient, and improve the respiratory situation. It is important to evaluate the patient's condition before giving sizable doses of morphine or pantapon. Demerol has proved to be a very effective sedative.

There has been a trend to decrease the rather widespread use of antibiotics in the so-called clean cases; that is, in those patients where infection is not a predominant element. After pneumonectomy, when the pleural space on the operated side is filling with the serohemorrhagic exudate, it is advisable to aspirate some of this exudate for culture if there is an unexplainable rise in temperature If organisms are cultured from this fluid, sensitivity studies should be made, and the proper antibiotic instilled.

Unexpected disruption of the bronchial closure is always a concern after pulmonary resection. It will lead to infection of the remaining space, to extensive subcutaneous emphysema, and, occasionally, to death from tension pneumothorax if it is not recognized. If drainage has been discontinued, this drainage should be promptly reinstituted. The bronchial fistula which may result may require closure by partial thoracoplasty. In this manner, the empyema space which has developed will be obliterated. It has been my personal experience, and the reported experience of others, that it is possible to sterilize a postpneumonectomy empyema by the proper use of antibiotics without resort to thoracoplasty.

Postresection thoracoplasty may be employed to obliterate the space left by pulmonary resection. This is particularly true after resections for tuberculous disease.

SURGICAL REPAIR OF DIAPHRAGMATIC HERNIA

The surgical repair of diaphragmatic hernia demands a knowledge of the normal anatomy of the diaphragm (Fig. 7-33), as well as of its embryologic origin and developmental defects (Figs. 7-34, 7-35 and 7-36). According to Bremer(17).

> The diaphragm in man consists primarily of the septum transversum, a sheet of connective tissue which, in very young embryos, forms the caudal limit of the pericardial cavity, and stretches from the ventral and lateral body walls to the ventral wall of the foregut (later esophagus) Behind the dorsa ledge of the septum on either side of the foregut the pericardial cavity connects freely with the peritoneal cavity. The two passages thus formed are to lodge the lungs and may be called the pleural passages Each becomes cut off from the pericardial cavity by the simple growth from the lateral wall of a thin membrane which ultimately reaches and fuses with the lateral wall of the foregut. The lower closure of the pleural passages is more complicated.

edge to edge, leaving at the gap a triangular area peripherally, later closed by fibrous tissue and known as the trigonum lumbo costale.

The completed diaphragm is thus a complicated structure, the result of a long series of developmental processes of diverse nature. In such circumstances it is almost axiomatic embryologically that the later steps in the process will be most subject to anomalous changes. One might expect, therefore, that the most common form of diaphragmatic hernia would be through the trigonum lumbo costale, the so-called foramen of Bochdalek.

The Abdominal Approach. In Adults. The esophageal hiatus hernia will be the most frequently encountered type. In those patients in whom surgical repair of the hernia is indicated, preliminary crushing of the left phrenic nerve under local anesthesia (Fig. 7-11) should be performed a few days prior to hernial repair. The success of this procedure should be checked by fluoroscopic observation of diaphragmatic mobility. The diaphragm should be elevated and should not descend on inspiration. The relaxed elevated diaphragm allows for more satisfactory repair without tension.

Under intratracheal anesthesia the abdomen is opened through a left paramedian incision extending from the xiphoid process of the sternum to the level of the umbilicus. It is necessary to have maximum relaxation of the tissues of the abdominal wall to obtain adequate exposure of the diaphragm from below. The colon and small bowel are placed in the lower abdomen and held there by properly inserted laparotomy packs. With the wound edges held widely apart by adequate assistance, the left lobe of the liver is freed from its attachment to the diaphragm by division of its suspensory ligament. This is usually avascular except as the division is carried near the midline. The Levine tube, which has been placed into the stomach preliminarily, is used to evacuate the air and stomach contents which may have accumulated during the induction of anesthesia. With the abdomen opened, a Levine tube which might have been passed with difficulty before surgery or could not have been passed at all, can be guided into the stomach and the stomach deflated. This will allow for more easy reduction of the herniated stomach when downward pull is exerted. The negative pressure effect from the thorax will be clearly noted as the hernia is being reduced. Release of the stomach will be followed by its prompt return into the posterior mediastinum.

Esophageal hiatus hernia has a true sac of the sliding type; that is, having the wall of the stomach contributing one surface of the sac in much the same manner as the wall of the cecum or sigmoid colon become a part of the sac in certain varieties of inguinal hernia. Often through its intimate peritoneal attachment to the stomach the spleen is drawn up into the hernial sac (Fig. 7-37). Downward tension on the stomach will put the walls of the sac on a stretch so that safe division can be begun (Fig. 7-38). As has been shown in Figure 7-33, the sac is made up of three distinct layers contributed by the anatomic structures of the hiatal region. These layers may be divided separately or together and the division should be complete so that their continuity will be completely interrupted. The upper portion will retract into the thorax whereas the lower edge in contact with the stomach will remain below the diaphragm. The edges of the enlarged esophageal hiatus are dissected free of the loose areolar tissue which has surrounded

Into the septum transversum grows the liver, an outgrowth of the foregut. It rapidly spreads ventrally to the body wall and dorsally as the two dorsal lobes into the two pleural passages. Everywhere it splits the septum into a thick upper and thin lower sheet. This part I have called the dorsal-septal extension. The fusion of the three edges of the extension, dorsal, lateral and mesial, with the body walls and mediastinum to effect complete closure is, however, not simple. The dorsal edges fuse with the tops of the adrenal glands which, being large and precocious in man, bulge forward from the dorsal wall to meet them. The lateral edges meet the pleuro-peritoneal membranes, structures which form the covering walls of small niches in the lateral walls. The two mesial edges have differing histories. On the right side a tubular niche develops in the wall of the mediastinum

Fig 7-35. Congenital-acquired diaphragmatic hernia The diaphragm viewed from below. The illustration is that of an abnormally large esophageal hiatus, in this instance having the esophagus centrally placed to emphasize the mediastinal location of these hernias They may extend well to the right of the midline within the sliding hernial sac All of them are considered to be congenital, but the added factors of trauma, increased intra-abdominal pressure, atrophy of supporting tissue in the elderly, and reflex irritation of associated upper abdominal disease constitute a valid reason for labeling them congenital-acquired They sometimes lie far enough posteriorly to seem to emerge through the aortic foramen

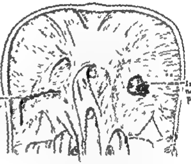

Fig 7-36. Acquired diaphragmatic hernia. The diaphragm viewed from below. Traumatic laceration of the diaphragm occurs either directly from missiles or stab wounds, or indirectly from greatly increased pressure If right-sided, the liver may be turned upward into the thorax. The stomach may be involved, and the fluid level in it mistaken for intrathoracic pleural fluid.

Least common of all diaphragmatic hernias are those resulting from erosion of the diaphragm by an abscess frequently subphrenic in location Careful investigation often will elicit the history of the etiologic process

Neither of these types has a sac In both, the presence of adhesions between the involved viscera and the diaphragm complicates the surgical repair.

lying in the pulmonary ligament, and the septal-extension meets and fuses partly with the mediastinum and partly with the membrane covering this niche. On the left side the stomach swings far to the left, crowding aside the dorsal lobe of the liver and its septal extension. Only after the stomach has descended lower in the abdomen do the hepatic lobe and the septal extension grow over it The extension then fuses with the mediastinum directly.

The septal structures form only the membranous portions of the diaphragm. The muscular parts are formed by the burrowing of the expanding pleural cavities into the body wall in such a way as to strip off the inner layer of muscle and fascia which then forms the peripheral part of the diaphragm. The burrowing starts from two points with a slight gap between and proceeds in two directions, first from behind the adrenal gland pushing caudally and mesially, and second, from the dorsolateral angle of each cavity extending around the ribs to the anterior thoracic wall. The muscles peeled off by these two separate processes later fuse

edge to edge, leaving at the gap a triangular area peripherally, later closed by fibrous tissue and known as the trigonum lumbo costale.

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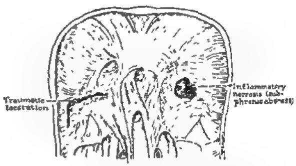

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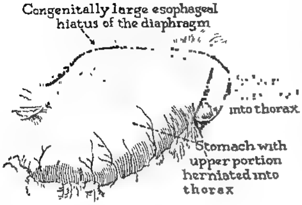

Fig 7-37. Large hiatus hernia Illustrates the abdominal aspect of the cardiac end of the stomach herniating through an enlarged esophageal hiatus The spleen is being drawn, with the stomach, into the posterior mediastinal portion of the thorax. In advanced degrees of herniation the colon may be drawn into the sac similarly by traction of the gastrocolic ligament. The negative intrathoracic pressure effect is very evident when attempt is made at operation to reduce the herniated viscera into the abdominal cavity

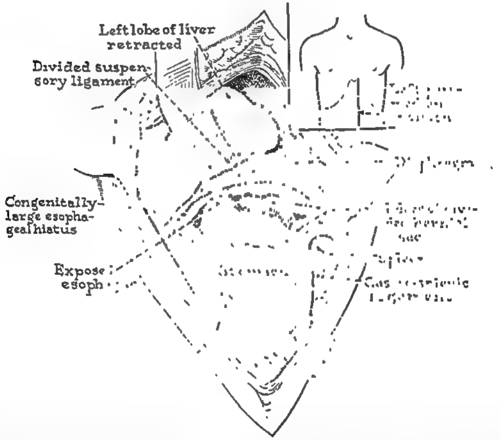

Fig. 7-38 The abdominal approach to repair of esophageal hiatus diaphragmatic hernia. The insert illustrates a left upper abdominal paramedian incision extending from the ensiform process to the umbilicus There has been a preliminary phrenic nerve crushing. The small ... d colon have been p..ked into the lower abdomen The suspensory ligament of the ... vided in its avascular portion and the liver retracted. Down- ... tended to invert the sliding hernial sac whose incised edges can be seen The anterior edge of the enlarged esophageal hiatus is evident The interruption of the continuity of the hernial sac is of utmost importance in the repair of these hernias. The edges of the hiatus will be cleared of loose areolar tissue, and repair of the congenital defect begun.

the hernial sac. A long tenaculum is used to grasp the outer edge of the hiatal orifice. Traction upon this instrument will make the diaphragmatic edges prominent so that a row of No. 1 black silk mattress sutures may be placed so as to overlap the more *available margin* (Figs. 7-39 and 7-40). At this point a regular size stomach tube is inserted into the stomach to

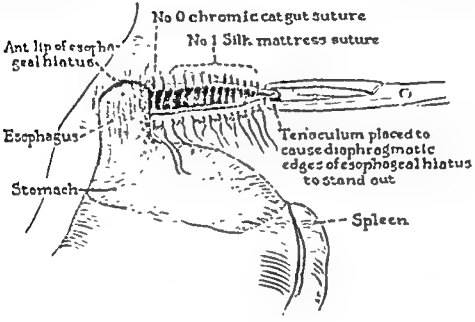

Fig 7-39 Diagrammatic illustration of the esophageal hiatal hernial orifice from below with placement of sutures. Interrupted mattress sutures of No 1 black silk are placed so as to produce overlapping of the diaphragmatic edges. A tenaculum grasps the outer edge of the [illegible] turing Absorbable suture of catgut [illegible] stomach tube to prevent too tight [illegible] more easy postoperative dilation if this closure produces any swallowing difficulty

Fig. 7-40 Completed closure of the esophageal hiatal hernial orifice Interrupted sutures of finer black silk secure the overlapped edge to the opposite leaf of the diaphragm The closure is thus reinforced

replace the Levine tube previously present. This would prevent making the closure too snug. Furthermore, the innermost mattress suture should be of No. 0 chromic catgut. This absorbable suture will permit postoperative dilatation in the event that there should be any dysphagia. A second row of No. 1 interrupted black silk sutures is then placed so as to secure

the free edge which has been overlapped to the opposite edge of the diaphragm.

The so-called short esophagus type of diaphragmatic hernia presents a further problem. Here the esophagus does not reach to the level of the diaphragm either because of a congenital shortening or from contraction of an inflammatory process in the lower esophagus associated with the absence of normal function at the cardioesophageal junction. The preliminary phrenic nerve interruption will allow the repair of the enlarged hiatus to be made from 2 to 3 cm. higher on the esophagus above the stomach. If necessary, further lengthening of the esophagus can be readily accomplished by division of one or both vagi without fear of postoperative complications, if careful attention is paid to decompression of the stomach until normal peristalsis returns. This will be slow if bilateral vagus section is performed. Often diaphragmatic hernias of the esophageal hiatus and short esophagus type are accompanied by peptic ulceration which may be a factor in the shortening and which will be considerably benefited by vagus nerve interruption. It has been shown in the experimental animal that division of the vagi not only produces a lengthening of the esophagus but also interrupts the reflex shortening which occurs from vagal stimulation from upper abdominal disease processes.

The parasternal (foramen of Morgagni) hernias (Fig. 7-34) ordinarily have a sac. The omentum is most commonly found to be involved. These hernias may be confused with anterior mediastinal tumors inasmuch as stomach and colon fluoroscopy will not demonstrate the presence of either of these abdominal viscera in the thorax. With the reduction of the contents of the hernial sac and approximation of the edges of the defect, adequate repair can be satisfactorily performed.

In Children. The abdominal approach is perhaps most satisfactory in the repair of congenital diaphragmatic hernia in infants and children. Very adequate exposure can be obtained because of the pliable nature of their tissues. It is ordinarily an advantage not to open the thorax. Preliminary phrenic nerve interruption need not necessarily be done unless exploration reveals a large defect whose closure may prove to be difficult.

Hernias through the lumbocostal trigone area (foramen of Bochdalek) are those most often seen in the newborn. They do not have a hernial sac. The most common viscus involved is the colon and with it often the cecum, appendix and loops of terminal small bowel. There may be symptoms of bowel obstruction or regurgitation of intestinal contents with aspiration pneumonia. These are the usual causes of mortality in infants so affected and demand immediate surgical repair when this malformation is diagnosed. In order to readily reduce the hernial contents, a catheter may be inserted into the thorax through the hernial opening allowing air to rise into the chest and reduce the upward pull of the negative intrathorax pressure. The diaphragm may be readily closed with a few interrupted sutures of black silk. During the repair of the diaphragm, the displaced viscera should be kept warm with laparotomy packs moistened with saline Whereas most of these hernias occur on the left, an occasional right-sided one will be observed despite the protection of the liver mass. These right-sided hernias can likewise, in infants, be adequately exposed through an abdom[illegible] inci-

sion. It is possible to displace the liver forward, expose the hernial opening, reduce the abdominal viscera from the thorax with the help of the pressure neutralizing catheter. Inasmuch as these congenital openings are most often small, they may be quickly closed with interrupted silk sutures. The major problem in the surgical repair of these hernias in infants is the return of the viscera into the abdomen which has not previously contained them. Ladd and Gross(18) have described a two-stage repair in which the subcutaneous tissue and skin of the abdominal wall are closed loosely at the time of the hernial repair. Closely placed fine interrupted silk sutures are used. At the end of a week a layer by layer closure from peritoneum to skin is performed after reopening of the wound. Care must be taken during this interval to prevent wound dehiscence. Another method(19) which may be used in place of the two-stage closure is that of manual dilatation of the abdominal wall This will allow for more ease in replacement of the abdominal viscera into their normal location.

Congenital absence of the posterior leaf of the diaphragm may make reconstruction impossible without further relaxation of the diaphragmatic edges. This may be accomplished by subperiosteal resection of the lower ribs, thus narrowing the diameter of the thorax. Full use of neighboring available muscular and fascial attachments must be made in order to successfully close these defects.

During the course of the operative procedure, blood and fluids should be administered by vein as needed. After surgery an x-ray of the chest should be made to be sure that there is no mediastinal displacement which will cause dangerous respiratory embarrassment. Air may be aspirated from the thorax on the operated side and normal pressure relations reestablished. The patient is then placed in an oxygen tent for 24 to 72 hours and longer if there are any signs of respiratory embarrassment. Careful postoperative blood studies are recommended so that replacement can be carried out. Every effort must be made to provide adequate oxygenation.

Precautions and Pitfalls. 1. Inasmuch as surgical repair of diaphragmatic hernias in adults is seldom an emergency, proper weight reduction in obese patients should be carried out preliminary to surgery. This is of utmost importance as pertains to the ease of surgical repair. Similarly it reduces the operative mortality as well as the likelihood of recurrence.

2. Because of the involvement of the spleen in esophageal hiatus hernia, injury to this organ may lead to troublesome hemorrhage during the surgical procedure. The spleen should always be inspected at the conclusion of the procedure and, if sufficiently traumatized, should be removed.

3. Occasionally in the postoperative period, it will be necessary to aspirate pleural fluid accumulation by thoracentesis. Small accumulations will absorb. Larger ones may produce dyspnea and will require aspiration.

4. In anterior mediastinal opacities, if a fluid level is discernible, needle aspiration is dangerous. These may be hernias through the foramen of Morgagni in which not only omentum but colon may be present.

5. The repair of diaphragmatic hernias in the newborn of the Bochdalek foramen type constitute a surgical emergency because of the immediate danger of bowel obstruction or aspiration pneumonia. Furthermore, if the hernial contents are massive, the lung of the affected side will be completely

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5. The repair of diaphragmatic hernias in the newborn of the Bochdalek foramen type constitute a surgical emergency because of the immediate danger of bowel obstruction or aspiration pneumonia. Furthermore, if the hernial contents are massive, the lung of the affected side will be completely

the free edge which has been overlapped to the opposite edge of the diaphragm.

The so-called short esophagus type of diaphragmatic hernia presents a further problem. Here the esophagus does not reach to the level of the diaphragm either because of a congenital shortening or from contraction of an inflammatory process in the lower esophagus associated with the absence of normal function at the cardioesophageal junction. The preliminary phrenic nerve interruption will allow the repair of the enlarged hiatus to be made from 2 to 3 cm. higher on the esophagus above the stomach. If necessary, further lengthening of the esophagus can be readily accomplished by division of one or both vagi without fear of postoperative complications, if careful attention is paid to decompression of the stomach until normal peristalsis returns. This will be slow if bilateral vagus section is performed. Often diaphragmatic hernias of the esophageal hiatus and short [illegible] which may be a factor [illegible] nefited by vagus nerve [illegible] animal that division of the vagi not only produces a lengthening of the esophagus but also interrupts the reflex shortening which occurs from vagal stimulation from upper abdominal disease processes.

The parasternal (foramen of Morgagni) hernias (Fig. 7-34) ordinarily have a sac. The omentum is most commonly found to be involved. These hernias may be confused with anterior mediastinal tumors inasmuch as stomach and colon fluoroscopy will not demonstrate the presence of either of these abdominal viscera in the thorax. With the reduction of the contents of the hernial sac and approximation of the edges of the defect, adequate repair can be satisfactorily performed.

In Children. The abdominal approach is perhaps most satisfactory in *the repair of congenital diaphragmatic hernia in infants and children.* Very *adequate exposure can be obtained because of the pliable nature of* their tissues. It is ordinarily an advantage not to open the thorax. Preliminary phrenic nerve interruption need not necessarily be done unless exploration reveals a large defect whose closure may prove to be difficult.

Hernias through the lumbocostal trigone area (foramen of Bochdalek) are those most often seen in the newborn. They do not have a hernial sac. The most common viscus involved is the colon and with it often the cecum, appendix and loops of terminal small bowel. There may be symptoms of bowel obstruction or regurgitation of intestinal contents with aspiration pneumonia. These are the usual causes of mortality in infants so affected and demand immediate surgical repair when this malformation is diagnosed. In order to readily reduce the hernial contents, a catheter may be inserted into the thorax through the hernial opening allowing air to rise into the chest and reduce the upward pull of the negative intrathorax pressure. The diaphragm may be readily closed with a few interrupted sutures of black silk. During the repair of the diaphragm, the displaced viscera should be kept warm with laparotomy packs moistened with saline. Whereas most of these hernias occur on the left, an occasional right-sided one will be observed despite the protection of the liver mass. These right-sided hernias can likewise, in infants, be adequately exposed through an abdominal inci-

collapsed and its reexpansion will take several days. If the hernial contents are compressed into an abdomen which has not previously contained them, anoxia will result through embarrassment to the one involved lung from increased intra-abdominal pressure. It is for this reason that the modifications in the closure of these patients are suggested.

The Thoracic Approach. The surgical exposure of diaphragmatic hernias through the thorax can be readily accomplished (Fig. 7-41). It is the method of choice of many surgeons. It is particularly of advantage in traumatic hernias, especially so if they are right sided. The combination of thoracic and abdominal incisions, either as midline, sternum-splitting prolongations upward onto the thorax, or lateral extensions across the costal arch onto the posterolateral thorax have also been used to considerable advantage(20). Under intratracheal anesthesia with the patient lying on the unaffected side in the lateral recumbent position, the thorax is opened through the bed of preferably the eighth rib, which has been resected from the costal cartilage anteriorly to the angle posteriorly. A rib spreader is placed so as to obtain adequate access to the thorax and the lower lobe of the lung. The phrenic nerve is crushed with a forceps as it descends to the diaphragm from the pericardium. The lower lobe of the lung is displaced upward by properly placed laparotomy packs soaked with physiologic saline solution held with suitable retractors

The mediastinal parietal pleura is divided longitudinally. The two innermost layers of the hernial sac are divided transversely exposing the wall of the herniated stomach The continuity of the sac is interrupted by complete dissection and division, thus baring the cardioesophageal junction. A counter opening is made in the diaphragm peripheral to the enlarged hiatus and downward pull on the stomach is made with a Babcock forceps. The edges of the hiatus are dissected free of the loose areolar tissue and the outer angle is grasped with a tenaculum. Traction on this instrument will sharply outline the edges of the defect and closure is performed by multiple interrupted mattress sutures of No. 1 silk. A second layer of finer interrupted silk sutures is placed so as to securely fix the overlapped layer. Again No. 0 chromic catgut is used adjacent to the esophagus for the reason mentioned

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Fig 7-41 Thoracic repair of the esophageal hiatus diaphragmatic hernia

The surgical incision through the posterior periosteum of the resected left ninth rib is shown in the insert The main drawing shows the hernia above the diaphragm and retracted somewhat laterally from the triangle which such herniations ordinarily occupy. This triangle is bounded anteriorly by the posterior pericardium, posteriorly by the aorta, and inferiorly by the dome of the diaphagm The sac is made up of parietal pleura of mediastinal and diaphragmatic origin, of the thinned out phrenoesophageal ligament (in reality, the transversalis fascia), and the parietal-abdominal peritoneum It may be "reefed" so as to bring the phrenoesophageal ligament at the esophagus to the under surface of the freshioned edge of the esophagal hiatus in the diaphragm It is profitable to excise the sac If there is any question about maintaining the length of the esophagus, the phrenoesophageal ligament at the esophagus may be sewn similarly to the freshened edge of the esophageal hiatus of the diaphragm which in turn is closed snugly about the esophagus as is illustrated The counter incision through which downward traction on the stomach is made to reduce the herniation above the diaphragm is illustrated in the lower left hand corner This is a very helpful maneuver When the tissues medial to the esophageal hiatus do not seem firm enough to afford a secure repair, the esophagus may be moved laterally or anteriorly in the diaphragm and a more secure closure effected about its entire circumference The author feels that the abdominal approach affords a better opportunity to securely close the hiatus about the esophagus

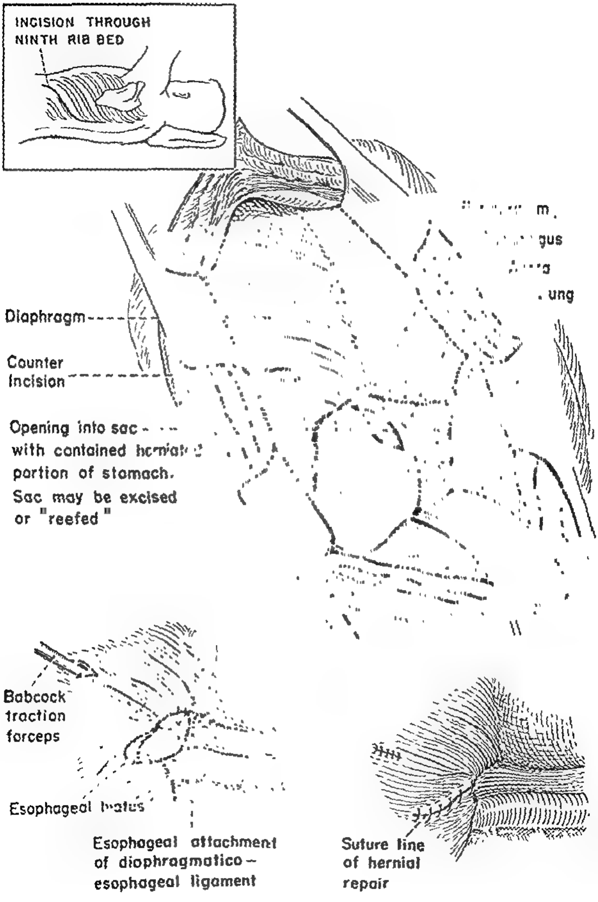


Fig. 7-41 For legend see opposite page

mal structures of the region. Heuer and Andrus(21, 22) have classified tumors as follows: dermoid cysts, teratomas, cysts of entodermal and mesodermal origin, cystic *lymphangiomas*, echinococcus cysts, fibromas, lipomas, leiomyomas, xanthomas, chondromyxomas, chondromas, chondrosarcomas, neurofibromas, ganglioneuromas, neuroblastomas, neuroepitheliomas, benign and malignant tumors of the thymus gland, lymphosarcoma, Hodgkins disease endotheliomas, primary and secondary sarcomas, primary and metastatic carcinomas, and, finally, goiters.

Realizing that any intrathoracic new growth may be one of these, certain generalizations are helpful in guiding diagnostic thought and treatment. Perhaps the most common mediastinal tumor is the adenoma of the thyroid which is substernal in location. It need not necessarily be completely intrathoracic to qualify as a mediastinal tumor. Further, it is recognized that the next most commonly found tumor in the anterior mediastinum is the dermoid. Tumors of this nature containing elements of one germ layer are called epidermoids, those with two are true dermoids, and those with three germ layers represented are teratomas. The midmediastinal growths are the tumors which arise most commonly from the structures near the bifurcation of the trachea. Tumors associated with lymph nodes are most often found here. The most common posterior mediastinal tumor is generally agreed to be the neurofibroma. It arises from the neurilemma sheaths of intercostal nerves. The related tumors of central nervous system origin such as the ganglioneuromas and neuroblastomas are also found in the posterior mediastinum.

Figure 7-42 illustrates diagrammatically a lateral sagittal view of the thorax through the mediastinum. Arbitrarily, the mediastinum is divided into anterior and posterior divisions. The anterior mediastinum has an inferior and superior division. In the region of circle number I would be found the tumors of the anterior superior mediastinum which would be largely those of thyroid and thymic origin. Dermoids would occupy this area, too, as well as the area of circle number IV. Also, in circle number IV would be the pericardial cysts, lipomas, and the more rarely encountered new growths. In circle number II would be the tumors at the hilum of the lung, and in circle number III the posterior mediastinal tumors which, as has been stated, are principally neurofibromas, but which may also be chondromas, chondromyxomas, chondrosarcomas, etc. Not illustrated are those shadows in the thorax which occur in the mediastinum through upward extension of intra-abdominal processes. These may be Foramen of Morgagni hernias which are confused with anterior mediastinal tumors, and partial eventrations of the diaphragm containing spleen or liver which are confused with mediastinal tumors in more posterior locations.

Symptoms. These are obviously variable depending upon the size and origin of the tumor. Occasionally a symptom may be pathognomonic of a particular type of tumor, for example coughing up of hair is indicative of the presence of a dermoid cyst Certain manifestations of inoperability are recognized; important among these are involvement of the cervical sympathetic producing a Horner's syndrome, hoarseness due to pressure upon the recurrent laryngeal nerve, or elevation of the diaphragm as an evidence of phrenic nerve involvement.

previously. In certain instances where the diaphragmatic edges of the hiatus are thin, fascia lata strips taken from the thigh with a fascial stripper and properly prepared may be used to advantage.

Acquired hernias of the traumatic type or from perforation by subdiaphragmatic inflammatory processes (Fig. 7-36) will require careful dissection of adhesions which inevitably accompany them. The involved viscera may be replaced within the abdomen and closure of the diaphragmatic defect accomplished.

Congenital hernias of the lumbocostal trigone most frequently occur in infants and children in whom abdominal repair is advocated. In those hernias where absence of a diaphragmatic leaf makes repair difficult because of the size of the defect, a combined abdominothoracic approach may be the method of choice. In closing the chest, catheter drainage is advocated. Either a Pezzar or Foley type catheter is led through a stab wound made in the ninth interspace. A rib approximator would allow the intercostal tissues to be approximated with multiple interrupted catgut sutures. The muscles of the thoracic wall are also approximated carefully with interrupted catgut and the skin closed with running silk. An inclusive dressing held in place by several strips of elastoplast adhesive, which in turn is secured at its ends by regular adhesive plaster, completes the closure. A bulb syringe is used to evacuate air from the chest through the catheter, which is then sealed with a ligature to be connected with a two-bottle underwater seal drainage apparatus in the patient's room. A roentgenogram of the chest is made before the patient leaves the operating room to ascertain the position of the mediastinum and the expansion of the lungs. The patient during the course of the surgical procedure should receive adequate amounts of blood and fluid. An oxygen tent is used postoperatively for 24 to 72 hours. The catheter is removed when in the postoperative period a portable roentgenogram discloses the lung on the operated side to be completely expanded.

Precautions and Pitfalls. 1. It is necessary to guard against too tight closure of the hiatal defect.

2. In the placement of sutures, the proximity of the aorta will be apparent. Care must be taken to avoid trauma by retractors.

3. Bronchoscopy at the conclusion of the surgical procedure is often advisable to remove accumulated secretions.

4. When sutures are placed through the diaphragm in the repair of the hernial defect, it is imperative that care be taken not to include any subdiaphragmatic tissue.

MEDIASTINAL TUMORS

The mediastinum is the space between the parietal pleural layers of the right and left pleural cavities where they are reflected from the thoracic wall and diaphragm to be in closest proximity to each other. It is bounded anteriorly by the sternum and posteriorly by the spinal column. It is in continuity with the neck through a continuation of the fascial planes which delineate potential fascial spaces. In general, it can be said that tumors in the mediastinum may have their origin from one or all of the primordial germ layers or their adult derivatives which have contributed to the nor-

culture, paraffin block studies, Papanicolaou stains of the sputum, appropriate x-ray views including planographic studies, occasionally diagnostic pneumothorax, occasionally needle biopsy, and more frequently advocated than ever before, exploratory thoracotomy are in order.

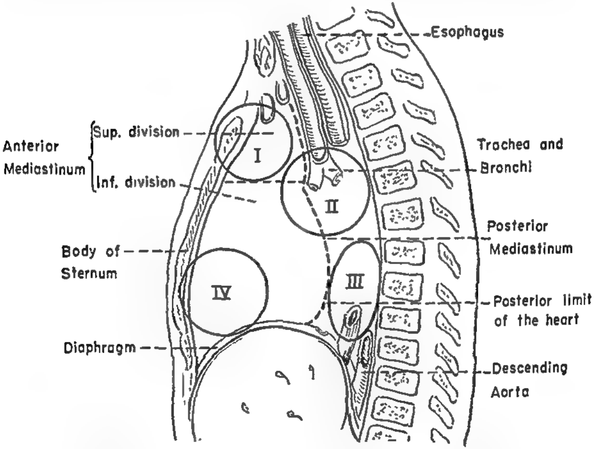
TREATMENT

A tumor of the mediastinum as any other intrathoracic tumor should be treated as are tumors of the breast. Its exact nature must be determined and the removal accomplished when possible.

Surgical Approach. 1. Posterolateral Incision. This is the most commonly employed method because it allows the most adequate exposure of the mediastinum. The disadvantage in transgressing the pleural cavity is made up for by the advantage of the excellent exposure of the lesion to be resected. The level of the incision depends upon the level of the growth to be exposed, and the anatomy of these incisions has been carefully illustrated. In the young, a rib need not be resected, but in those individuals of the middle and later periods of life, it is better to resect a rib, and to divide ribs above or below in order to secure adequate working room. Airtight closure of the thorax is advisable with complete reexpansion of the lung through the use of catheter drainage attached to a negative pressure apparatus. When drainage ceases and the postoperative roentgenogram discloses that the lung on the operative side is completely expanded, then the catheter may be removed, and a pressure dressing applied over the point of its withdrawal from the chest wall.

2. The Anterior Approach. More use is being made of sternum- splitting incisions from above downward for extension of cervical processes into the anterior mediastinum, and from below upward for the purpose of adequate exposure in this area. The sternum should be divided with a Lebsche knife being careful to protect the structures of the anterior mediastinum from inadvertent injury. The sternum may be spread over its entire length or the incision may be carried into an intercostal space if the more extensive exposure is not necessary. In so doing, it is important to prevent injury and hemorrhage from the internal mammary arteries. These should be ligated preliminarily when possible, within the operative field. The sternum may be reapproximated with multiple stainless steel wire sutures placed through its entire thickness, or simply through its anterior table. The anterior fascia of the sternum can be approximated with either fine silk or catgut sutures to cover the projecting end of the wire. If there is any anticipated difficulty from retention of bronchial secretions, it is preferable to do an "on the table" prophylactic tracheostomy in association with the sternum-splitting incision. This is an innocuous procedure, and it is far better to do it electively than ineffectively as an emergency after too much time has elapsed. Because of the reported rather high incidence of malignant change in thyroid adenomas, a word could be said for the advantage of the sternum-splitting incision wherein complete removal without morcellation can be carried out. Morcellation would tend to implant tumor in the event that such adenoma contained a malignant change. However, sternum-splitting should be reserved for selected cases.

Certain signs, both from laboratory studies including x-ray examination, and from physical examination, are of diagnostic importance. It has long been recognized that a circumscribed, spherical tumor with smooth outline is not necessarily benign. Hard cervical, or axillary lymph nodes must be searched for and studied when they are present in association with a mediastinal shadow on x-ray. The fluid level sometimes seen in anterior mediastinal tumors caused by fat floating on fluid is pathognomonic of dermoids. The use of a test dose of roentgen therapy as evidence in the diagnosis of a tumor has very little to offer. Except when surgical intervention is contraindicated, it should not be employed because of the delay which it causes.



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The diagnosis of indeterminant mediastinal shadows should be carried out in a very systematic way. Careful history, physical examination, blood studies, including bone marrow examination, sputum, direct smear and

culture, paraffin block studies, Papanicolaou stains of the sputum, appropriate x-ray views including planographic studies, occasionally diagnostic pneumothorax, occasionally needle biopsy, and more frequently advocated than ever before, exploratory thoracotomy are in order.

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3. THE POSTERIOR APPROACH. Posterior mediastinotomy has been largely abandoned in favor of the transpleural posterolateral approach. However, it has a definite place in the armamentarium of the thoracic surgeon. If mediastinotomy is to be accomplished without tearing of the parietal pleura, it is important to observe certain principles. A long segment of the rib directly over the area to be investigated should be removed with multiple short rib resections above and below. In this way, the parietal pleura may be reflected so as to expose the posterior mediastinum without tearing of the pleura. This is most important when there is infection within the operative field.

Precautions and Pitfalls. 1. Because tumors of the anterior mediastinum may be of thymic origin, and because tumors of the thymus are frequently accompanied by at least incipient symptoms of myesthenia gravis, extreme care should be exercised in avoiding the use of curare as a drug in combination with the other anesthetic agents. Should respiratory difficulty develop in the postoperative period after removal of anterior mediastinal tumors, it would be well to consider the administration of prostigmine, or any of the antimyasthenic drugs which have been developed.

2. The place of tracheostomy as an elective rather than as an emergency procedure cannot be overemphasized.

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8

THE FACE, MOUTH, JAWS, AND NECK

JAMES BARRETT BROWN AND FRANK McDOWELL

FACIAL INJURIES

Severe blows about the face may produce extensive fractures with only contusions on the surface, and widespread soft tissue lacerations may not be complicated by fractures. However, the two occur together so often that the care of the soft parts and of the bone cannot be separated and careful consideration of the possible occurrence of fractures should be made in all patients. If it is assumed that fractures can be considered and cared for after swelling has occurred and subsided, the best chance for correct bone replacement is missed. If the true picture is recognized, simple procedures for bone replacement and fixation usually suffice. Special splints are seldom required although it is important to have someone on hand who understands the dental requirements because one of the most important functions to maintain is mastication, and this requires that the teeth occlude naturally.

The number of complications possible makes the problem in severe injuries difficult, and one should be alert to make as complete a diagnosis as possible and have his findings recorded either before or at the time of operation. If tissue has been completely lost, this is of great importance in the final outcome and the extent should be noted. Skull fracture and brain injury, damage to the cervical spine and lesions of the orbit and the eye itself are very frequent and always should be looked for, recorded and treated as indicated.

Final union in upper jaw fractures may never be solid because of the thin plates of bone present or because of infection. In the lower jaw there is usually solid union but the fracture line may remain visible in the x-ray.

X-ray Examination. It is not necessary to rush these patients to the x-ray room, because manipulation might be contraindicated if there were skull or cervical spine damage. However, when safe for the patient, complete views of all involved regions should be taken.

For the lower jaw, complete views of both sides including both condyles should be taken, because multiple fractures may be missed even at operation.

Roentgenograms of the facial bones should be taken, but are apt to be somewhat disappointing due to the superimposition of shadows in this area. The heavier ridges of bone show quite well in the antral and verticosubmental positions, but there may be many comminutions of the maxilla, ethmoid, nasal and other thin bones that are entirely missed on the x-ray plate. Therefore, this condition has to be searched for at the time of operation.

When to Do Primary Repair. The primary repair should be done as soon as the patient's general condition permits and in the first 20 hours if possible, before swelling, organization of clots, and infection have occurred.

If seen after this initial period and there is the necessity of manipulation through contaminated clots and edematous tissue, it is sometimes better to just approximate the soft parts and await the subsidence of swelling before replacing the bone fragments. However, the replacement of bone fragments rarely should be delayed longer than 7 to 10 days, because the fixation of small, comminuted chips after this time may make their accurate realignment impossible. Shock and neurologic damage may necessitate delay and an intoxicated patient should not have his jaws wired together.

Fig. 8-1. Deep injection of second and third divisions of trigeminal nerve. Above bony landmarks are located by palpation, and a lumbar puncture needle is inserted between the coronoid and condyle just beneath the zygomatic arch. It is directed toward the same point on the other side of the face and inserted until it strikes the pterygoid plate. (From Brown, Surg., Gynec. & Obst., 53:832, 1931.)

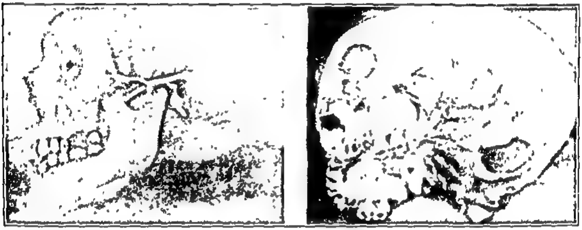
Type of Anesthesia. In many of these patients nerve blocks, especially deep injections of the branches of the fifth nerve (Figs. 8-1 and 8-2), are the most satisfactory for anesthesia. Occasionally field blocks or local infiltration suffice. These may or may not be combined with a basal anesthetic such as avertin. General anesthesia is to be avoided when possible, but is often necessary, especially in children. When used, the endotracheal method is almost always employed, though occasionally endopharyngeal insufflation is sufficient in very small children. Intravenous anesthetics may create serious airway problems.

General Operative Procedures. In extensive injuries, it is often best to wait until the patient is in the operating room before manipulating the tissues simply to find out the extent of damage. There should be determination and recording of the loss or tearing of all the features and the extent of detachment of bones. The steps necessary to carry out the repair should then be determined and systematized into a definite, orderly procedure.

Cleaning of these facial wounds is extremely important and should be done with soap and water followed by ether and saline irrigations so that local antiseptics are seldom necessary. The decision of when to clean and when to anesthetize is somewhat difficult. It is often best to clean as far as possible with the patient enduring it, and then get the local or block

anesthetic in, or proceed with the induction of general anesthesia if it is necessary and safe to do so. Oil ground in to abrasions is difficult to remove and may require scrubbing with a brush and the use of solvents such as ether or benzine. Bits of glass from rear vision mirrors or from completely broken shatterproof glass are especially apt to be overlooked and for this reason it is well, if possible, to find out whether or not any glass was broken at the time of the accident.

Meticulous cleaning should constitute almost the entire débridement. The usual plan of wide excision of all torn edges should not be practiced in the face. Very ragged edges may be smoothed by minimal clean excision,



A B

Fig 8-2. A, *straw shows approximate relation of needle to bony landmarks.* After striking pterygoid plate, needle is partially withdrawn and inserted in a more upward direction until it strikes the angle between it and the great wing of the sphenoid. B, by partially withdrawing and reinserting the needle, it is worked forward in this angle until it drops off the plate into the sphenomaxillary fissure, where 3 ml of 2 per cent novocain (containing ½ drop of epinephrine) is injected to anesthetize the second division. Similarly, the needle is worked backward *along the angle until it just drops off near the foramen ovale where the same amount of novocain* is injected to anesthetize the third division (Ten minutes may be required for the solution to infiltrate the nerves It is important not to go posteriorly or deep more than ½ to 1 cm. from the plate, and to aspirate to be certain the needle is not in a blood vessel) (From Brown. Surg., Gynec & Obst , 53.832, 1931.)

remembering that the loss of even 1/16 of an inch in a child's eyelid or ala may be deforming. Extreme conservatism should also be the rule in dealing with loose bone chips, as it is probably better to leave in some bone fragments that might die, than to needlessly discard any good supporting fragments that might live.

Bone Replacement. If the nasal airway is occluded, it can be reestablished by carefully introducing a long speculum and dilating it and then slipping a good-sized rubber tube through the meatus on each side; other bone replacements should then be done, such as elevation of orbits and the nose.

If the lower jaw is fractured, attention may be given to it at this time. If the patient is under general anesthesia, the individual dental wires may be placed, but the jaws should not be wired together until he is awake and has ceased vomiting.

The care of the various types of facial fractures will be considered under separate paragraphs, but it is usually best to complete as much of the bone

replacement as possible before diverting attention to the soft tissue repair.

SUTURE OF SOFT TISSUES. For suturing the soft parts, new cleaning can be done and fresh instruments used if the mouth secretions can now be avoided. Surface key sutures may be used for the known points and these may have to be deep, but should never be wide, as wide suture marks can never be completely obliterated. Between these, buried No. 000 white silk sutures should be used to completely approximate all wound edges unless the skin edges are so thin that these cannot be put in. The remaining surface sutures are then placed not more than 1 or 2 mm. from the wound edges to obtain the final fine adjustment. No. 0000000 black silk usually suffices and may be removed in one to four days. Stay sutures may be put in from the inside of the cheek or nose. If they are needed on the outside, they should always be tied over a gauze pad to prevent cutting across the wound and leaving a permanent scar.

Fig. 8-3 Cheek torn open from an automobile door handle catching in angle of mouth. The known points are the junction of the skin and vermilion on the upper and lower flaps. These are united first. The lateral points of the upper and lower flaps are then united, and the remaining areas successively bisected with 000 white silk subcuticular sutures and 0000000 black silk skin sutures put in not more than 1 to 2 mm from the edges. Mucosa carefully closed in same manner. Stay sutures put in from inside to avoid any wide suture marks on the face.

In complicated tears (Fig. 8-3) a correct replacement may be difficult, but a start is made at some known point such as the nostril border, or the edge of an eyebrow. If none can be figured out, closure may be started in the center of the wound, and the remaining areas bisected successively until complete closure is obtained. If the final adjustment is not satisfactory, one should not be reticent in completely opening and resuturing it. Triangular or trap-door flaps should be adjusted with particular care to avoid late deformity, especially about the lids, nose, and mouth.

Small drains may be placed advantageously, ordinary rubber bands sufficing for small wounds. If the immediate covering of the wound is of fine mesh grease gauze, it may be removed later with minimal trauma to the wound edges and sutures. A firm pressure dressing of mechanic's waste or marine sponges should be applied overall to minimize hemorrhage and swelling and, thereby, infection. The dressing should be regarded as a part of the operation and should be carried out with the same meticulous attention to detail.

Fractures of the Lower Jaw. The treatment varies according to the site of the fracture, but complicated appliances can be dispensed with in almost all instances. The keynote of the treatment, as in all other fractures, is accurate reduction of the fragments followed by immobilization. The patient's sensations may be of great assistance in telling when his natural occlusion has been reestablished. No attempt to improve upon the patient's former occlusion should be made in the treatment of these fractures.

Fig. 8-4. Ordinary Gilmer interdental wiring suffices for most fractures of the mandible. Number 24 stainless steel wire is anchored around individual teeth, strands on opposing teeth are then twisted together to immobilize the jaw in occlusion. Above illustration shows importance of leaving in posterior molar teeth which may be in fracture lines or loose. They often serve as splints to hold the other fragments in position.

In the majority of fractures in older children or adults with good teeth, immobilization may be accomplished by ordinary Gilmer interdental wiring from the four lower premolar teeth to the corresponding upper premolar teeth (Fig. 8-4). In addition, it is a good plan to have at least one set of interdental wires posterior and one set anterior to the fracture site if possible. The tooth in the fracture line should usually be left in place during

the period of immobilization, even if it is a little loose. This is especially true of molar teeth, which often prevent the tendency to upward displacement of the posterior fragment in this area (Fig. 8-4).

Symphysis fractures usually require a dental arch or band in addition to the above, to prevent the tendency to "rocker motion" of the fragments. The method of Risdon is an excellent one in caring for these fractures (Fig. 8-5).

Fig. 8-5. Method of Risdon in applying an anterior arch by putting long wires on the posterior teeth, bringing them around in front, fastening them together, and then anchoring individual teeth to this arch with finer wires. Besides this support, which is used mainly for symphysis fractures, fixation to the upper jaw with the teeth in normal occlusion is done. (From Brown, Surg., Gynec. & Obst., 68:564, 1939.)

Fractures of the condyles are frequently amenable to attempts at closed reduction followed by ordinary interdental wiring. It is usually not necessary to consider open reduction or primary excision, unless the condyle is completely out of the glenoid, notwithstanding many statements which have been made to the contrary.

Edentulous jaws may require circumferential wiring of the mandible to the patient's dental plate or to his upper teeth, direct wiring of the bone fragments, or internal fixation with Kirschner wires.

If the soft tissues have been torn off the jaw exposing the fracture site, it is usually most expedient to do direct wiring of the fragments (Fig. 8-6).

A small dependent drain should be placed directly up to the fracture site, unless one is reasonably certain that it is not compounded into a tooth socket.

Internal Fixation of Mandibular Fractures with Kirschner Wires. Internal fixation with Kirschner wires is the simplest and most positive fixation for many fractures of the mandible in which one or both fragments are edentulous. The method requires two surgeons and an electric power drill (or a drill attachment on an electric bone saw). One surgeon reduces the fracture, lines the fragments up, and holds them in position while the other one drills the wire longitudinally along the bone, across the fracture site, and well into the other fragment. The wire point should be sharp and the drill run at not too high speed to avoid any heat necrosis of the bone.

A single wire suffices for most fractures, but if the fixation does not seem to be solid enough, some auxiliary method of fixation may be used, or a second wire may be put through above the first one in a totally edentulous jaw (Figs. 8-7 and 8-8). When teeth are present, and a singe wire is used, it is usually possible to keep it below the nerve canal and any tooth roots.

Fig 8-6 Extremely widespread soft tissue injury plus complete separation through the symphysis Direct wiring of symphysis fracture through the open wound plus careful closure of soft tissues Complete restoration in one operation which was done a few hours after the accident (From Brown Surg, Gynec. & Obst., 68:564, 1939.)

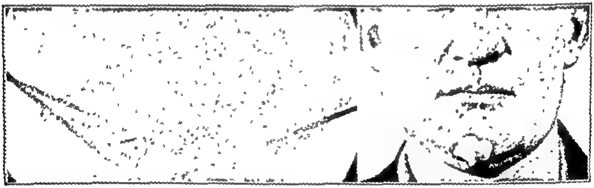


Fig 8-7. Internal Kirschner wire fixation of fractures in front of both angles in a man with very few teeth Long posterior fragment on right side edentulous and one on left side contains just one tooth Interdental wires also were left on a few days Patient returned to work within 10 days and solid union was obtained (From Brown and McDowell Surg., Gynec. & Obst, 75.361, 1942)

The whole procedure is done in the operating room with all possible sterile precautions and dependent drainage of the fracture site is instituted if necessary The wire is cut off about 1 cm outside the skin and the end is kept covered with a small dressing until it is removed, usually four to eight weeks later.

Displacement of Bones of the Upper Jaw. *Transverse facial fractures* occur usually from heavy blows dispersed over the face. There may be a level of separation at the frontal-zygomatic suture line and at the glabella

on both sides; there may be one through the wall of the antrum that may extend all the way around and involve the pterygoid region; and frequently there is a complete separation entirely around just above the dental arch. The whole face may sag down and become noticeably elongated, and the dental arch may be completely loose to the patient's own sensation and on moving it with examining fingers (Figs. 8-9 and 8-10).

Fig 8-8 A, bilateral fracture in a totally edentulous jaw. Patient was able to put the upper and lower dental plates in and eat soft foods after the first week, though the lower plate was painful if left in continuously Returned to work in 2½ weeks B, angle and mental foramen fractures in an almost edentulous jaw C and D, fixation of an almost edentulous jaw in an insane man, which was solid enough to hold without any cooperation. (From Brown and McDowell Surg, Gynec & Obst, 75 361, 1942)

Nasal, septal, and palate fractures frequently occur along with the above separation, and these small thin bones may be comminuted into multiple pieces. The nasal structure, including the cartilages, may be completely crumpled, and there may be one or more complete lacerations through the palate caused by the disrupted bone cutting through; the nasal passages may be completely occluded also (Fig. 8-11).

A single wire suffices for most fractures, but if the fixation does not seem to be solid enough, some auxiliary method of fixation may be used, or a *second wire may be put through above the first one in* ■ *totally edentulous* jaw (Figs. 8-7 and 8-8). When teeth are present, and a singe wire is used, it is usually possible to keep it below the nerve canal and any tooth roots.

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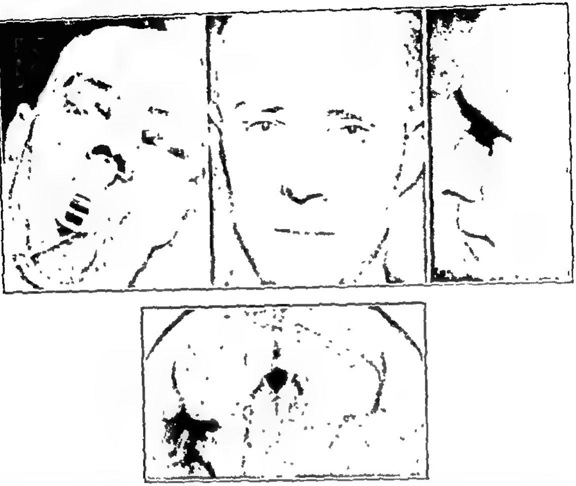
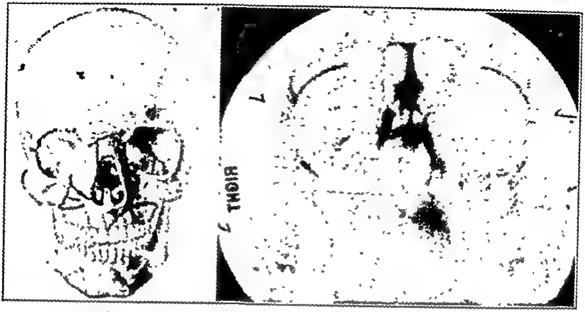


Fig. 8-11. Comminution of the facial and frontal bones with involvement of the frontal sinuses, displacement of the inner canthi, and flattening of the nose. Patient seen a few hours after the accident and restoration done immediately, that is, replacement of the comminuted fragments, rubber tube left in the frontal sinus to drain into the nose, fragments of the nose held up and inner canthi replaced by through-and-through wire sling, placed through the fracture lines of the frontal processes and held over lateral lead plates on the outside of the nose. Restoration of the nasal bridge and normal direction and situation of the inner canthi in one operation. (From Brown Surg., Gynec. & Obst., 68:564, 1939.)

The Zygomatic Bone and Orbit. The zygomatic bone (malar or cheek bone) frequently receives the blow but is itself seldom broken. Instead, it is torn loose from its moorings at the frontal, zygomatic process of the temporal bone, and the maxilla. The main displacement will be according to the direction of the force; if from the front, the zygomatic process will be crumpled back and broken by the zygoma itself; if from the side, the ascending ramus of the zygoma may be tipped in and impinge on the orbital space. In nearly all loosening of this bone, the antral wall crumples, and if it should sag down too much, the orbit becomes elongated and the globe may descend so much that binocular vision is impaired (Fig. 8-12). Blindness may result from section of the nerve by a loose thin piece of bone and from intraocular or direct ocular damage. The extraocular muscles and nerves may also be torn. The lacrymal apparatus may be impinged on if the frontal process of the maxilla is driven in.

Inner canthus displacement occurs if the nose with the frontal processes of the maxilla is crushed backward, there being an actual chiseling open of the front of the face. This deformity is as important as any other in which



A B

Fig 8-9 A, diagram of frequent separations of the upper jaw and facial bones, to which should be added a horizontal fracture all the way around on both sides just above the alveolus B, multiple comminutions of the facial bones, some of the areas having been scratched in for clearness Separation of the zygomatic-frontal suture lines, crumpling of the zygomatic arches and comminution about the orbital borders and antrum. (From Brown. Surg., Gynec. & Obst., 68 564, 1939.)

Fig 8-10 Early and late postoperative views of patient who had nose flattened backward until level with cheeks, and multiple comminuted fractures of other bones in the middle third of the face. The nasal bones were dug out of the face and held out forward by a double wire sling anchored on either side over lead plates as shown. Symphysis fracture held by Risdon arch and interdental wiring (see Fig 8-5). Upper jaw fracture maintained in occlusion by interdental wiring Orbital floor held up and cavity of maxillary sinus reestablished by iodoform gauze packing in the latter. (From Brown Surg, Gynec & Obst, 68 564, 1939.)

vidual patient all parts have to be considered and it is not possible to consider bone or soft tissue repair entirely alone. A few further noteworthy subjects are as follows:

Where wide areas of soft tissue have been lost, as good a closure as possible should be made, with an accurate notation of the estimated loss for future reference in repair. If necessary, simple closure of skin to mucosa can be done.

If orbital borders are left down too long there may be such derangement of the ocular muscles that binocular vision may never be attained, even though the globe is later raised.

Late lip scars often become so hard that it may be thought that a foreign body has been left; this is apparently due to the glands that are present, and occasionally is relieved by radiation.

If the late deformities are studied, the requirements of early care may be made more clear. Wide suturing, infection, misplacement of flaps, failure to accurately replace bone fragments, and keloid formation seem to account for most deformities. However, some secondary repairs are necessary in almost all extensive injuries, and this possibility should always be considered from the start with the patient or some responsible relative.

THE TREATMENT OF FACIAL PARALYSIS

The facial nerve may be interrupted intracranially, e.g., in removal of eighth nerve tumors, in the fallopian canal, e.g., mastoiditis or mastoidectomy, in the face after it has divided into several branches, e.g., in lacerations or from removal of parotid tumors, or it may be congenitally absent. When divided intracranially, anastomosis with the hypoglossal nerve may be considered. When divided in the fallopian canal, resuturing or free nerve grafts may be considered. However, when the individual branches have been cut, in the face, or when the nerve is congenitally absent, support of the paralyzed face with transplanted strips of fascia lata seems the best procedure; this operation may also be used in conjunction with the nerve operations for intracranial or canal injuries, or may be used after them if the nerve operations do not work as well as desired.

The Operation. Endotracheal anesthesia is employed with the tube coming out of the opposite corner of the mouth. Strips of fascia lata about 1 cm. wide are obtained in the longest lengths possible from the iliotibial band, by use of the Masson or other stripper. The temporal incision is made in the hairbearing area and is carried down to the temporalis fascia. A small stab opening is made in the middle of the upper lip and another one in the lower lip 1 to 2 cm. inside the angle of the mouth and 1 cm. below the vermilion. The first strip is then passed subcutaneously from the temporal wound down through the face, out the upper lip stab opening, and back up to the temple by a different route so that it forms a loop and encircles a good deal of soft tissue in the lip. Another strip is passed similarly down to the stab opening in the lower lip and back, care being taken again to avoid puncturing the buccal mucosa. The fascia may be carried through the face by a special fascia needle, or by an ordinary long sack-sewing needle (Figs. 8-13 and 8-14).

to accomplish an early repair, because, if left until fixation occurs, the canthi probably never will be sunken in normally again (Fig. 8-11).

Nasal flatness goes along with the canthus displacement and the two are corrected together by withdrawing the depressed tissue and bones, molding them into their normal positions, and frequently holding them there with through-and-through silver wire sutures inserted under the separated frontal processes and held on the outside of the nose over lead plates (Fig. 8-10).

Fig 8-12 Depressed orbital border [illegible] c
arch crumpled Incision made through [illegible] d
through fracture line in its anterior face [illegible] o
place. Antrum packed with iodoform gauze for one week Photographs show late result with restoration of binocular vision. There had also been extensive tearing of the ear and nose (From Brown, Surg, Gynec. & Obst, 68.564, 1939)

The general rule for repair is simply to replace these fragments and maintain them in position with the least manipulation possible. This replacement amounts to an open reduction, and access to the orbital border can be gained by a short incision in the buccal fornix, then into the antrum through the fracture line that is almost always present. The depressed border can then be elevated into position with a Kelly clamp. This bone may be locked in place, but, if there is much comminution, the whole number of fragments, including the anterior and lateral walls of the antrum, may be "mulched" in position and held with an iodoform pack in the antrum, with the end left just through the opening in the fornix.

Qualifications of Treatment. A detailed account of the care of all the fractures and other complications cannot be included here, but in the indi-

into the normal side. He must learn that balance in the face is more important than the actual range of motion and always strive for this balance. As a starting point, he may consciously try to remain a little glum and then work from this point forward as he learns better to control his expressions. Sudden large laughs can never be balanced adequately in these patients, and may reveal a paralysis which is otherwise pretty well controlled.

Fig. 8-15. Congenital paralysis of 20 years duration. Result of single operation (fascial transplant). (*From Brown and McDowell. J.A.M.A., 135:18, 1947.*)

Fig. 8-16. Total paralysis resulting from removal of malignant parotid tumor. All of the branches were individually severed in the parotid area. After one operation (fascial transplant) the patient appears quite normal in repose and with a small smile. (From Brown and McDowell. J.A.M.A., 135:18, 1947.)

Variations in the Operation. Preserved fascia, kangaroo tendon, and wire have been used, but it is thought that autogenous fascia is superior to any foreign material and it is easy to obtain.

Additional loops may be put in to the prominence of the cheek, around the mouth, or to the angle, but the two simple slings described usually suffice.

The anchorage above may be to the temporal fascia or to the zygomatic arch, rather than to the muscle, but this does not permit any movement of

After being placed, the loops are worked back and forth a little to take out any slack and the temporalis fascia is opened about 1 inch above the coronoid to expose the muscle fibers. Using a heavy full curved fascia needle, one end of each strip is passed around a good segment of muscle and tied to the other end by a surgeon's knot. The knots are pulled taut with the mouth in considerable overcorrection and then fixed by several interrupted wire stitches through the knots and by sewing the ends of the strips down. A pressure dressing is applied to cover the eye, ear and entire side of the face and helps materially in getting smooth early healing.

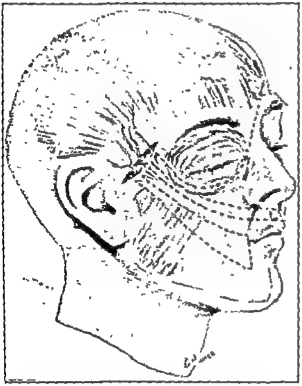


Fig 8-13 Pathways of the subcutaneous fascial loops. The two lower loops are the ones commonly employed, the upper strip being used only when it is impossible to correct the lagophthalmos by a canthoplasty or other local operation on the lids (From Brown and McDowell J A M A, 135 18, 1947.)

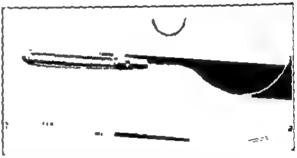


Fig 8-14. Three needles ordinarily used for placing the fascial strips. From above downward, Gallie needle used for anchoring the strips in the temporal muscle; semicircular needle used for placing strip in lower lid, long needle used for placing the main strips in the face. The lower two needles were devised by Dr. R. Douglas Sanders and are made of bent heavy Kirschner wires with a large eye cut through near the tip and a handle attached on the other end. (From Brown and McDowell. J.A.M.A, 135.18, 1947.)

Postoperative Care. The pressure dressing is left on four or five days (if the eye is comfortable) and then replaced by a smaller one. Chewing is limited for the first week, but is gradually resumed as any tenderness in the temple subsides. The overcorrection disappears within about 10 days and after two or three weeks, the patient may practice biting down in front of a mirror until he can produce some lateral movement of the mouth. He notes how this is done and then strives to increase the extent of the movement. A little later he may try to balance the movement with a small smile on the normal side (Figs. 8-15 and 8-16), and meanwhile should practice repressing massive movements on the normal side. This latter point is emphasized, as almost any patient with a facial paralysis will try so hard to move the paralyzed side that he forms the habit of throwing exaggerated movements

the less is to be expected from any operative procedure, as the net gain will be less.

The chief disadvantages of the operation are, 1, the occasional necessity of secondary adjustments outlined above, and 2, that in common with all other operations, it does not restore completely normal movements to the permanently paralyzed face.

Advantages that might be listed are, 1, its simplicity and directness; 2, early definitive results, 3, no resulting annoying tics or mass actions and little possibility of complete failure, 4, it can be used later when nerve operations have not been as successful as anticipated or desired; 5, can be used in conjunction with nerve operations; 6, can be used in practically all patients, regardless of etiology or duration, and 7, does not produce any additional disability or visible scars.

TREATMENT OF TUMORS OF THE FACE

Excision of Skin Tumors. Small warts, moles, fibromas, papillomas, keratoses, and even carcinomas (Fig. 8-17), are often best removed with the fine electric cautery (the Ziegler type employed by the ophthalmologists with a fine platinum wire tip that heats white hot is useful for this purpose; the radio-frequency machines may destroy an unnecessary amount of tissue and one must guard against sparks jumping to the cornea or elsewhere).

Fig. 8-17 Basal cell carcinoma excised with fine, white hot, electric cautery, cutting through the normal skin all around the lesion and then cutting through the normal fat under the tumor. Specimen, with small margin of normal tissue, removed in one piece. Wound granulates up and heals by secondary intention in about three weeks. (Middle photograph was taken immediately after excision, to show width and depth of removal.)

Novocain is injected under and around the lesion and tension is made in all directions by an assistant's fingers to stretch the skin taut. The cautery wire is used as a bloodless knife, cutting all around the lesion down into healthy, subcutaneous fat and then staying within the layer of fat while cutting across beneath the lesion. The wound granulates up and heals by secondary intention, usually requiring two to three weeks. A small dressing is kept on it during this time.

the face or even enough to take any slack out of the loops if they stretch or slip a little.

Older persons with paralysis of long duration may have considerable excess skin. This may be excised by a unilateral face-lifting operation as a separate procedure. It is a little safer to do it before the fascial transplant, but the amount to be excised can be estimated better afterwards. Younger individuals, or those with paralysis of lesser duration, will usually tighten up the stretched skin spontaneously during the first few postoperative months.

The Eyelids and Forehead. The paralyzed upper lid seldom requires any treatment (unless combined with third nerve paralysis) but the sagging lower lid may create a large palpebral fissure, apparent or actual exophthalmos, and a staring expression. The general elevation of the face usually helps this and nothing else is required in some cases. If this is not sufficient, a small external canthoplasty may be done, uniting a small section of the two lids together near the outer canthus. Occasionally, it is worthwhile to put a thin fascial strip horizontally through the lower lid near the tarsal border, anchoring it externally to the temporal fascia above, and medially to the opposite frontalis muscle or fascia (Fig. 8-13). These operations do a lot to prevent irritation to the globe, but it is always advisable for these patients to avoid excessive exposure to strong, cold winds or to dust.

No known operation will restore movement to the forehead. However, if the brow is heavy and low, it may be elevated by excising an ellipse of skin in the hairline just above, undermining and sliding that side of the forehead up. A separate strip of fascia may be put in, from high in the temporal region, through the brow and then carried high up on the opposite side and anchored.

The amount of movement obtained varies from little to a noticeable amount, the majority having a small range of definitive motion which is of value in expression. The cause of this variation is not entirely understood, though some individuals seem to have much thicker and more active muscles than others. An occasional patient will have the fascial loops "freeze" to all of the surrounding tissues throughout their length and this almost precludes movement, but leaves a balanced face in repose which is still worthwhile. The patient's own efforts and general morale have a good deal of influence on the final result in many cases.

The point of initial overcorrection might be mentioned again, as we have never had to loosen any of these loops secondarily (even when the mouth was pulled far over to the paralyzed side) though we have had to tighten a few and insert additional loops in a few later. The single operation suffices in nearly all patients, and it is not entirely clear why an occasional one will need secondary tightening. It may be due to: 1, stretching of the fascia (or not using wide enough strips), 2, the loops cutting through some soft tissue above or below (the reason for encompassing as much soft tissue at either end as possible); or 3, persistent overactivity on the normal side.

The most dramatic results are obtained in total paralysis, but worthwhile results have been obtained in partial paralysis (where nerve operations would be contraindicated). However, the closer these latter are to normal,

by complete hemostasis before closing the skin and a good pressure dressing afterwards.

The resultant subcutaneous defect is filled in by mobilizing little flaps of fat from either side of the wound and suturing them in place with interrupted 000 white silk. The same sutures are used to approximate the derma, and tiny interrupted 0000000 black silk sutures are used for the skin, putting them on a very fine, half curved, cutting needle such as the ⅝- inch Lane cleft palate needle.

Small sebaceous cysts can sometimes be removed by making a tiny opening with a stab blade knife and teasing out the entire lining with a chalazion curet.

Larger sebaceous cysts will nearly always have at least a tiny area of skin attachment. This area must be surrounded by a small elliptical incision so as to remove the attached skin with the cysts. Infected sebaceous cysts are always drained preliminarily and excised when entirely quiescent. It is sometimes best to drain noninfected cysts when large, squeezing or curetting all the sebaceous material out of them, and allowing them to heal. This may reduce them to about one-fourth their former size, rendering the subsequent excision of them easier and producing a smaller scar.

Treatment of Hemangiomas of the Face. Hemangiomas of the face may be divided into three types: arterial, port-wine stains, and venous.

The arterial hemangiomas are bright red, growing tumors appearing in the skin of newborn or very young babies. They destroy the skin as they grow and rapidly increase in thickness so that they are elevated. While it is true that some of these tumors may disappear spontaneously after a few years, they may destroy or disfigure features in the meantime so that they generally should be treated, with some exceptions being made when they can be closely observed and seem to be retrogressing.

The small ones of only a few millimeters in diameter are usually best destroyed with the fine, white hot, electric cautery (after anesthetizing the area with novocain). Larger ones on a flat surface (such as the forehead) which are only a few millimeters thick may be treated with surface radium, using about 25 mg. hr./sq. cm. and shielding it with ½ mm. lead and 1 mm. rubber. Any additional treatments should not be applied in less than six weeks and should be reduced in amount. It is not necessary for the tumor to entirely disappear in six weeks, and if definite signs of retrogression are present any secondary treatment is postponed until it seems stationary or there are signs of renewed activity of the lesion.

Thicker ones, or lesions appearing on moving or curved areas (such as the lips or eyelids) are often best treated with interstitial gold radon seed, using ⅛ mc. or 1/10 mc seed implanted about 1 cm apart. The smaller seed should be used in thin areas such as the nose, eyelids, or lips or on the more rapidly growing, brighter tumors covered with very thin epithelium. The larger seed can be used on the remainder, but should be spaced just a little further apart. It is seldom necessary to repeat the treatment on any one area (Fig. 8-19).

Port-wine stains are more of a congenital anomaly in the number of capillaries within the derma than tumors and they are not sensitive to radiation. They are purely a cosmetic problem, but a very serious one.

Larger lesions can be excised elliptically in the known lines of skin tension with the knife and closed by undermining and suturing, using interrupted 000 white silk sutures subcutaneously and in the derma and interrupted 0000000 black silk sutures in the skin, put in not more than 1 to 2 mm. from the wound margin. The suture line is covered with fine mesh grease gauze and a pressure dressing applied when possible. Sutures may be removed in from two to five days if the wound is supported after that with adhesive strips, fine mesh collodion gauze, or some combination of these.

The defects from sharp excision cannot be closed by direct suturing when they are large, or when such a procedure would pull on or distort some adjacent feature. In such instances, one may try to devise a satisfactory closure by rotation of local flaps, or it may be necessary to use free skin grafts (Fig. 8-18). Small to medium grafts of good texture and color can often be obtained from the clavicular area; larger grafts from the lower abdomen and inguinal area; or very thick split grafts from the lower anterior chest wall. Each patient requires individual selection of the best donor area.

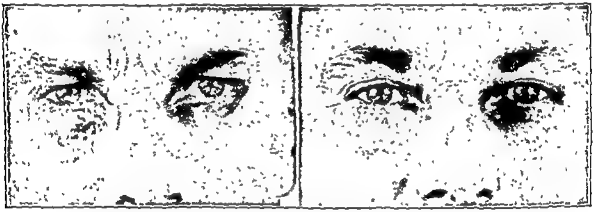


Fig. 8-18. Wide surgical excision of basal cell carcinoma of lower eyelid and immediate closure of wound with thick split-skin graft. Any attempt to suture this wound, or healing by secondary intention, would have produced a marked ectropion. Any possible radiation effect on the eye is avoided

Radiation therapy is sometimes used for basal cell carcinomas, especially the larger ones when located away from the nasal cartilages or the eyes, and can be used for some squamous carcinomas. A word of caution is necessary in treating the latter in patients with "sailor's" or "farmer's" skin (atrophy, telangiectases, and keratoses from long exposure to sun). Any radiation which is scattered elsewhere on such a skin may accelerate the degenerative processes in it.

Excision of Subcutaneous Tumors of the Face. Lipomas, dermoid cysts, deep fibromas, and other benign subcutaneous tumors are excised through an incision made in one of the known lines of skin tension. Any spurting vessels are grasped with a fine mosquito forceps and tied with 000 white silk; oozing is controlled by prolonged pressure with 1:5,000 adrenalin sponges or hot saline packs. Hematomas are one of the major causes of postoperative infections or irregular healing in the face, and are prevented

Excision of Parotid Tumors. The common tumor of the parotid gland is the mixed tumor. More than three fourths of them are benign and well encapsulated when they first come to the surgeon, and they would not present much of a problem except for the scars incident to their removal and especially the very real danger to the branches of the facial nerve during the excision.

The commonest cause of facial paralysis is the removal of parotid tumors by surgeons inexperienced in this work. Paralysis of one or more branches of the nerve, or recurrence of the tumor is probably the rule, rather than the exception, in such instances. The recurrent poor advice to extirpate the entire parotid for these benign anlage tumors is increasing the incidence of such postoperative facial paralysis. Either paralysis or recurrence will be quite rare if the surgeon has proper training and experience in this work, but no simple or radical plans will take the place of these essentials. Judging from a cross-section of the results that are seen and reported, the satisfactory excision of benign parotid tumors (without the sequelae of deformity or recurrence) might be considered as specialized surgery.

The mixed tumor is a firm, rounded mass, freely movable under the skin and over the ramus, but attached to the parotid tissue. It is not tender and the skin over it is not reddened. Stenson's duct will be open on probing, and the saliva from it will be clear. Sialograms are of little value in the diagnosis. The tumor must be differentiated from sebaceous cysts which will usually have some skin attachment, and from enlarged lymph nodes in the tail of the parotid. The presence of other enlarged lymph nodes, or of squamous carcinoma in a location which drains to this area will help in the diagnosis. It must be differentiated from suppurative parotitis (with or without stone) in which pus will be draining from Stenson's duct, and from epidemic parotitis (mumps) in which the gland will be tender, the enlargement diffuse and of short duration, and often redness around the opening of Stenson's duct. Lipomas in the area will be soft, and hemangiomas compressible. Unilateral hypertrophy of the masseter muscle may be difficult to differentiate, but the swelling will usually be soft when the jaw is relaxed and hard when it is clenched.

Malignancy of a mixed tumor can be diagnosed preoperatively when there is paralysis of any of the branches of the facial nerve, fixation to the skin, mandible, or mastoid, or enlarged hard nodes in the upper carotid sheath below the tumor, or lung metastases.

The excision is best done under general endotracheal anesthesia and it is essential that the entire face be exposed during the entire operation. The principal danger is the possibility of damage to any of the branches of the facial nerve and this must be kept in mind throughout the operation.

The incision is made just inside the tragus of the ear, down between the lobe of the ear and the face, back up behind the ear, and then down and forward in one of the horizontal creases in the upper neck (Fig. 8-20, left) The skin flap thus outlined is then completely undermined and reflected forward to expose the entire parotid area. The lobe of the ear is detached from the parotid and sutured up out of the way if necessary. The

Small ones can sometimes be excised and closed by undermining the edges and suturing, or by local rotation of flaps, or by multiple partial excision. Larger ones will often require excision and resurfacing of the area with full thickness or very thick split skin grafts. Some work has been done in injecting permanent pigments within the derma in these lesions, but results, in general, have been disappointing. Flat, light lesions on girls' faces are probably better handled by covering with cosmetics, than by any surgical treatment presently known. The original cosmetic problem may be made much worse by scarring from such treatments as acids, caustics, boiling water, dry ice, radiation, etc.

Fig 8-19. Growing, destructive, arterial hemangioma of lip in baby treated with interstitial radon seed This type of tumor may entirely destroy a feature if left alone. (From Brown and Byars, Am J Surg., 39.452, 1938.)

Venous (or cavernous) hemangiomas are subcutaneous collections of dilated veins which are compressible, are distended when dependent, and collapsed when elevated. Many of them probably contain arterial leaks. Their color varies with their proximity to the surface—lesions which have thinned out the overlying skin may be blue. Excision is the best treatment when applicable, but may be difficult for large ones in the cheek (because of danger to the facial nerve branches) and in some other locations. When excision seems contraindicated, injection with 5 per cent sodium morrhuate solution or some other endothelial sclerosing agent may be helpful. The solution should always be injected within the luman of the vein and not more than 2 to 3 ml. should be used each time, even in adults. On other lesions which cannot be satisfactorily excised, for various reasons, multiple suture ligation with fine chromic catgut, put in subcutaneously or submucously, may be helpful.

8-21, left). Small deep retractors, or a nasal speculum, may be used to gain exposure at this stage. The field is frequently washed out with saline to keep it from becoming even slightly blood-stained. The dissection is done entirely by spreading until the main trunk is identified. If there is any question, it can be lightly tapped and the whole face will twitch. The trunk is then followed distally until it branches, and each branch followed out individually until it is dissected free from the gland and the tumor. After all branches have been dissected out and retracted out of the way, the tumor may be removed with a generous amount of parotid adherent to it (Fig. 8-21, right). If there is any suspicion that it is malignant, the entire

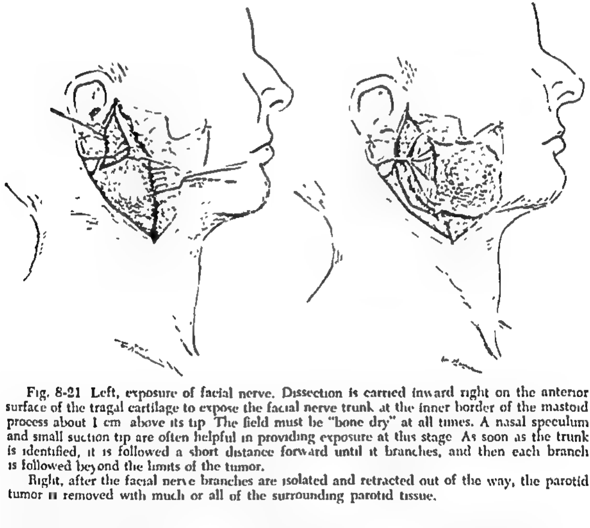


Fig. 8-21 Left, exposure of facial nerve. Dissection is carried inward right on the anterior surface of the tragal cartilage to expose the facial nerve trunk at the inner border of the mastoid process about 1 cm above its tip. The field must be "bone dry" at all times. A nasal speculum and small suction tip are often helpful in providing exposure at this stage. As soon as the trunk is identified, it is followed a short distance forward until it branches, and then each branch is followed beyond the limits of the tumor.

Right, after the facial nerve branches are isolated and retracted out of the way, the parotid tumor is removed with much or all of the surrounding parotid tissue.

parotid may be removed, but routine removal of the entire parotid for isolated benign tumors is neither necessary nor advisable. These tumors may push some of the nerve branches superficial and others deep. Experience with a large number of these tumors does not verify the hypothesis that the parotid can always be opened up like a book to expose the entire facial nerve structure. The method of operation advocated in this chapter has proved reliable over a long period of time with no recurrences and no paralysis. In tumors known to be malignant beforehand, of course, the facial nerve is disregarded and the entire parotid is excised with the definite understanding with the patient that facial paralysis will be produced, and a neck dissection may be done at the same time.

entire field is then made completely dry by tying off any spurting vessels with 000 white silk and stopping any oozing with pressure with 1:5,000 adrenalin sponges (Fig. 8-20, right).

Fig 8-20. Left, line of incision for removal of parotid tumor. The lower end can be carried farther forward for larger tumors.

Right, skin flap undermined and reflected forward to expose the tumor and adjacent parotid. The lobe of the ear can be detached from the parotid and fastened up to the helix when necessary for exposure

If the tumor is not large and any portion of it seems quite superficial, it may be possible to remove it without doing a nerve dissection. In doing this, a sharp-nosed straight mosquito forceps without teeth is used for the dissection, pushing in the tip a few millimeters and spreading the blades in a direction that is always parallel to any of the nerve branches in the area (it is essential to be completely familiar with the detailed anatomy of the facial nerve for this operation). While a trusted assistant watches the face, any vertical fibrous septa thus encountered are very lightly squeezed with the forceps and divided if there is no twitching. It is essential that the most experienced assistant watch the face throughout the operation, and that the field be kept completely dry at all times. The initial dissection is done horizontally over the most superficial part of the tumor, and then carried by degrees all around the tumor, staying just a millimeter or two outside the capsule at all times and taking care not to puncture it.

If the tumor is large, or deep seated, a nerve dissection is essential preliminary to the actual removal To expose the main trunk of the nerve, the dissection is carried down on the anterior surface of the tragal cartilage, staying right on the surface of the cartilage to avoid any bleeding. The trunk will be found emerging horizontally, deep to the parotid, from the inner surface of the mastoid process and about 1 cm. above its tip (Fig.

8-21, left). Small deep retractors, or a nasal speculum, may be used to gain exposure at this stage. The field is frequently washed out with saline to keep it from becoming even slightly blood-stained. The dissection is done entirely by spreading until the main trunk is identified. If there is any question, it can be lightly tapped and the whole face will twitch. The trunk is then followed distally until it branches, and each branch followed out individually until it is dissected free from the gland and the tumor. After all branches have been dissected out and retracted out of the way, the tumor may be removed with a generous amount of parotid adherent to it (Fig. 8-21, right). If there is any suspicion that it is malignant, the entire

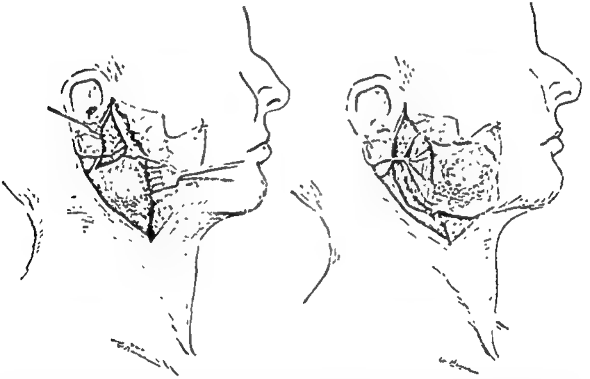


Fig 8-21. Left, exposure of facial nerve. Dissection is carried inward right on the anterior surface of the tragal cartilage to expose the facial nerve trunk at the inner border of the mastoid process about 1 cm. above its tip. The field must be "bone dry" at all times. A nasal speculum and small suction tip are often helpful in providing exposure at this stage As soon as the trunk is identified, it is followed a short distance forward until it branches, and then each branch is followed beyond the limits of the tumor.

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After removal, the wound is thoroughly irrigated with saline, the ear lobe sutured back in place if it was detached, and the skin flap replaced and closed with fine interrupted 0000000 black silk sutures around a small rubber dam drain placed to the tumor bed. A large pressure dressing is applied over the whole area, and the drain and sutures removed about the fifth day (Fig. 8-22).

Fig 8-22 Removal of medium-sized parotid tumor which, however, went in quite deep and required a complete nerve dissection. All branches of nerve preserved and resultant scar *is almost invisible*

REPAIR OF SINGLE CLEFT LIPS

Types of Operations. *V-excision of the cleft* and bringing the edges together is the most simple type of repair for single cleft lips (Fig. 8-23A). This plan has been used by many surgeons, with good results, particularly in partial clefts. One objection to it is the straight-line scar which may contract to produce a notch or "whistling" deformity. Another objection is that the lip which is produced comes straight down (as seen in the profile view) from the nostril floor to the vermilion.

The normal lip curves forward (in profile) just above the vermilion border. This break normally occurs about two-thirds or three-fourths of the way down the lip and a repair which reproduces this kick-out of the vermilion and the skin just above it will more closely resemble a normal lip (Fig. 8-23B, J). To do this, one needs to use a design which will give an extra amount of tissue in this region and to close the tissues firmly up toward the top of the fornix on the inside. It is thought that a small triangular flap does this more effectively than the old square (or Hagedorn) flap.

The essentials of the plan are that: 1, a V-excision operation is marked out first; and 2, then instead of completing this operation, a small triangular flap is designed on the cleft side to turn down and across to the central side. This saves tissue, fills out the lower border, and (when careful mucosal closure is done) leaves a protruding lip.

At the primary operation, it is of major importance to obtain: 1, a symmetrical alar level; 2, a good alar direction toward the columella; 3, satisfactory nostril floor; 4, a normal nostril curve, that is—across the tip;

5, a straight columella; 6, a full lip border in advance of the lower lip with a normal concavity from above downward (this might be called a flexion crease); and 7, a full vermilion without a notched whistling deformity. It is necessary to get primary healing, but this is usually not difficult if care is taken in the accurate apposition of raw surfaces and in avoiding tension by the wide mobilization of surrounding facial tissues.

Anesthesia. Ether vapor seems to be the safest sedative for babies. If both infraorbital nerves are blocked by injecting 2 per cent novocain around the region of the foramina, much less ether will be needed. The vapor is blown through a long, curved, sterile metal tube which is held about 1 or 2 inches from the mouth. The anesthetists are encouraged to give just enough so that the baby will remain reasonably still, but not enough to abolish the cough reflex, and it is better to err on the light side. An assistant uses a sucker from time to time to keep the mouth clear of blood. The operator sits above the head of the patient, thus seeing the face upside-down throughout the operation. Intratracheal gas-ether is used when the patients are old enough (in adults, local anesthesia usually suffices).

The marking is done with care after due consideration of all of the elements of deformity in the individual patient. Time spent at this stage will save operative time later because a good design can be followed throughout the operation without change. A mechanical drawing pen and 5 per cent alcoholic methylene blue are used, puncturing in the dots, scratching in the lines, and wiping off any excess dye with an alcohol sponge.

Marking out the V-excision Operation. To mark point A, the columellar side of the lip is pushed over into the cleft until the columella is straight and in the midline (Fig. 8-23A). A is then punctured near the mucocutaneous junction on the level of the base of the columella. (It may be put in on this line while it is still in its diagonal position.) Point X is punctured in the floor of the other nostril in a position corresponding to A.

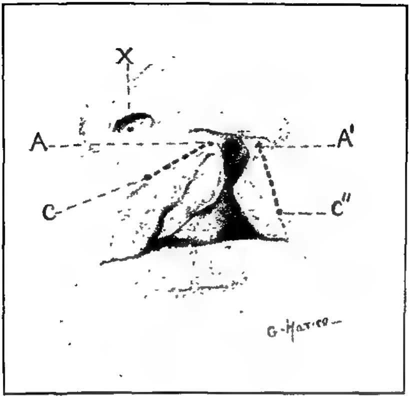
The relationship of X to the curve around the base of the normal ala is noted. A′ is then placed in the same relation to the base of the ala on the cleft side. If it is difficult to determine the grooves between the ala and cheek and lip, these landmarks can usually be brought out by temporarily pushing the lip medially over into the cleft.

C is on the mucocutaneous line, at the medial end of the full thickness of vermilion. This point, where the vermilion first begins to thin out, can be best ascertained by looking at the lip from above. At times it is almost over to the philtrum on the normal side.

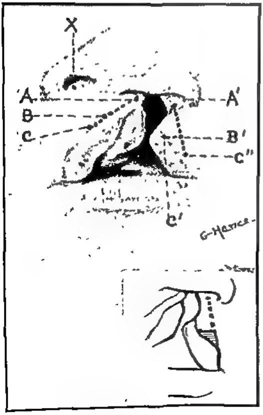
C″ is on the mucocutaneous line, the same distance from A′ that C is from A. A small caliper is useful for measuring these distances.

To do the V-excision operation, lines are drawn from A to C and A′ to C″, the edges of the cleft are excised accordingly and fitted together. This operation is not used except in a few partial clefts and in a few secondary operations. It is the easiest design to carry out.

Marking out the Flap Operation. The V-excision operation is marked out first (Fig. 2-23B, C) C′ is then located on the mucocutaneous junction at the highest point where the vermilion on the alar side is still of full thickness. This point, where the vermilion first begins to thin out, is again most easily seen from above the patient (Fig. 8-23B).



A



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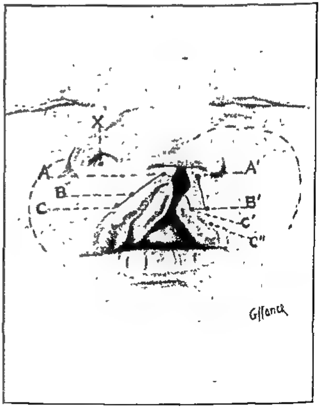
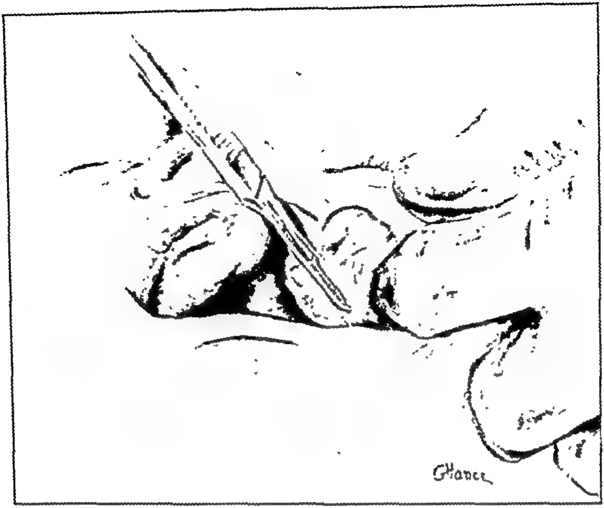


C

Fig 8-23 Operation for primary closure of single cleft lip See text for explanation. (From Brown and McDowell Surg, Gynec. & Obst, 80 12, 1945.)



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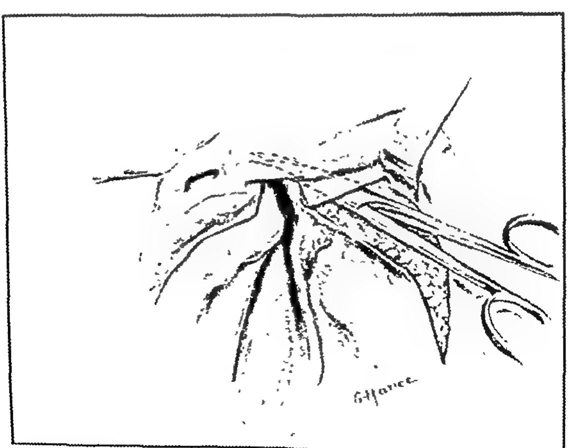
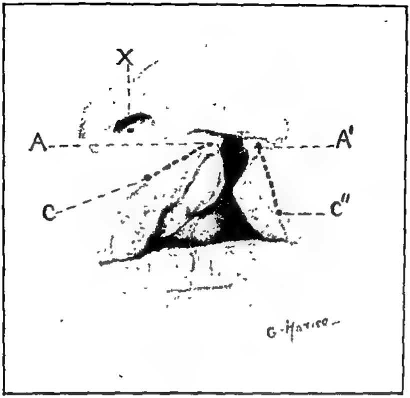


E

Fig 8-23 (cont) Operation for primary closure of single cleft lip Further steps. (From Brown and McDowell Surg., Gynec & Obst., 80.12, 1945.)



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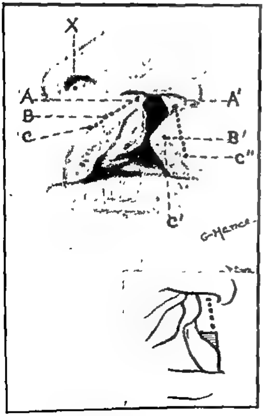
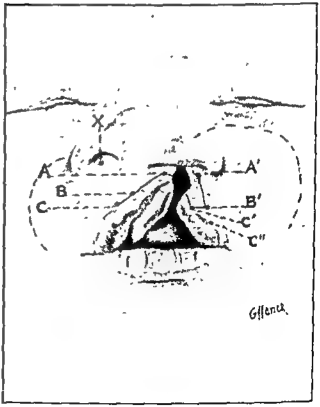
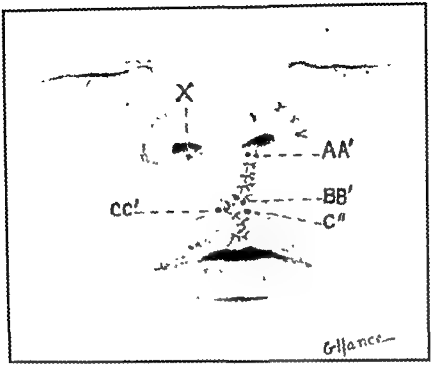




B C

Fig 8-23 Operation for primary closure of single cleft lip See text for explanation (From Brown and McDowell. Surg, Gynec & Obst, 80 12, 1945)



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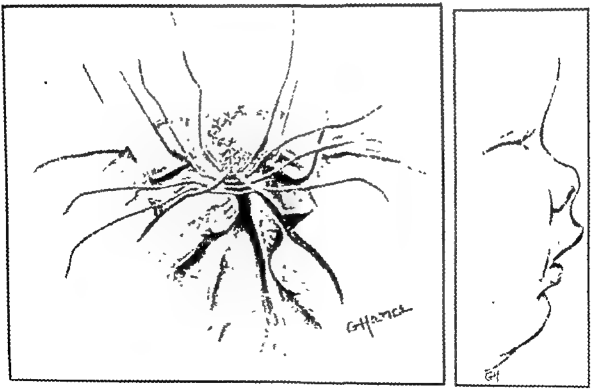

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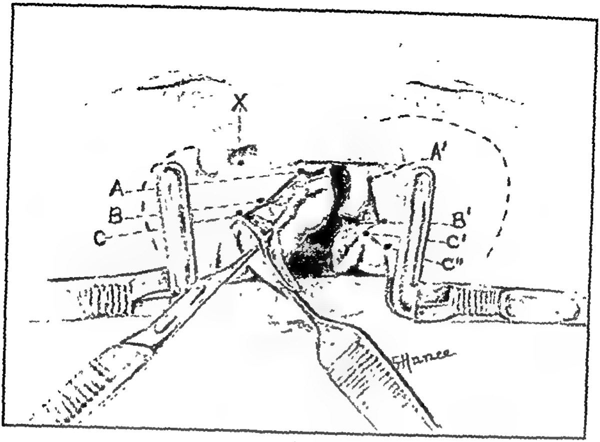
Fig 8-23 (cont) Operation for primary closure of single cleft lip Further steps (From Brown and McDowell Surg, Gynec & Obst, 80 12, 1945.)



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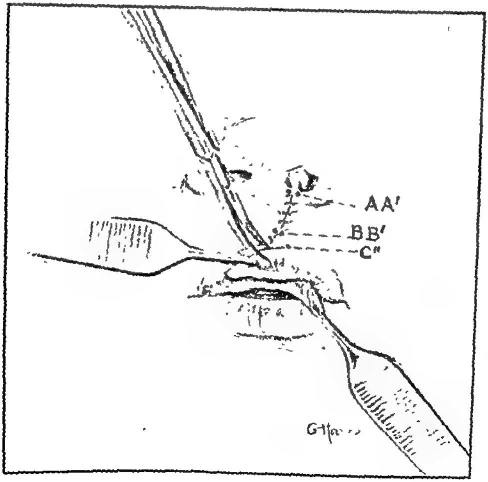

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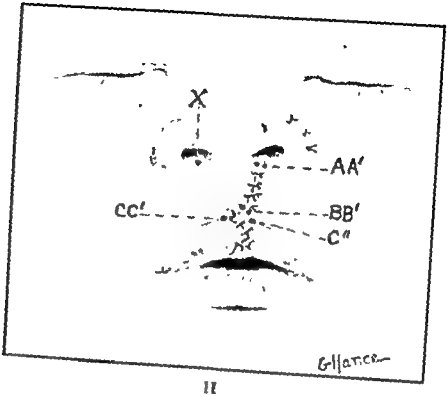
Fig 8-23 (cont) Operation for primary closure of single cleft lip Further steps (From Brown and McDowell Surg, Gynec & Obst 80 12 1945)



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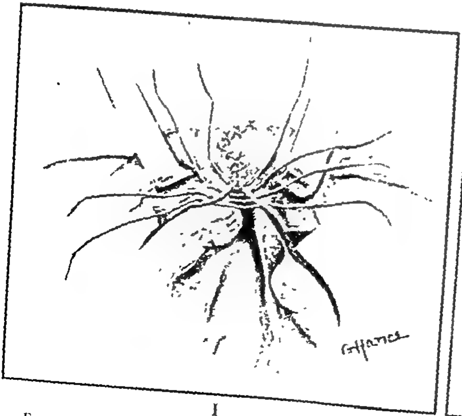

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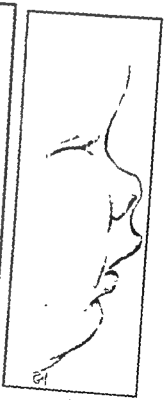

J

Fig 8-23 (cont) Operation for primary closure of single cleft lip Further steps (From Brown and McDowell Surg, Gynec & Obst, 80.12, 1945)

B′ is on the line A′—C″ and equidistant from C′ and C″. The isosceles triangle C″—B′—C′ is the Mirault flap and is the additional amount of lip which is saved by this operation. B′ is usually about one-third or one-fourth of the way up from C″.

B is on the mucocutaneous line and the same distance from C that B′ is from C′.

Discussion of Marking. Any error in placing A′ should be on the low side. The lower the mark, the higher the cleft nostril will be and this is the reverse of the common deformity.

An additional check can be had by measuring the distance from X vertically down to the mucocutaneous junction. A—C should not be greater than this distance, or the lip will be too long, a common error.

Both C and C′ should be opposite good thick vermilion. This is one of the instances in which two halves cannot be satisfactorily joined to make a whole, and if either of these points is opposite thin vermilion, a whistling defect is almost certain to result. However, if either of the points is placed too far laterally, an unnecessary amount of lip will be sacrificed.

Due to the curvature of the surface of the lip, one is measuring "air distances" rather than "ground distances" in locating all of these points. This would seem to be a source of error, but in practice these inequalities usually cancel each other.

The Operation. After one is satisfied with the marking, the lines A—B—C and A′—B′—C′ are lightly incised with a knife (Fig. 8-23D through J). The mucosa is also divided from the skin above A up in the nostril. The incision on the other side from C′ is carried upward into the nostril along the mucocutaneous junction. A rectangular skin flap is thus outlined between C′ and A′ and may be used later, if necessary, to form the nostril floor by rotating it 180 degrees up into place (Fig. 8-23C).

Mobilizing the Lip and Nose. An incision is made in the buccal fornix on the cleft side, extending from the molar region forward to the cleft (Fig. 8-23D). The soft tissues of the cheek are elevated carefully from the bone up toward the orbital border. This freeing of the cheek should allow that side of the lip to be brought easily across the cleft and the nostril to be rotated into its proper position. If tightness of the lining of the nose prevents this, it may be necessary to make a small vertical incision in front of the anterior end of the inferior turbinate (Fig. 8-23E). After the lip and ala are freely mobilized, small scissors are introduced through the buccal fornix and the skin of the nose is elevated throughout the lower half and over across the midline toward the normal side (Fig. 8-23E). This tends to minimize corrugation of the lining when the nostril is rotated inward and up to its new position, and possibly helps establish a columellar-alar angle instead of the straight line that is present here in wide clefts. The undermined cheek is packed temporarily with one-fourth strength adrenalin on gauze.

Similar mobilization of the lip (but not the nose) is done on the opposite side, though it is usually not so extensive. If the nose is badly deviated, it may be necessary to elevate the base of the normal ala up out of the pyriform recess with a small periosteal elevator Sometimes it may also be necessary to make a small cut across the base of the septum underneath

the lip. When *mobilization is complete*, the two sides of the lip can be brought together with practically no tension.

Excising the Cleft. The lines A′–B′–C′ are now cut through the full thickness of the lip, care being taken to keep the level of the cut on the mucosal surface identical with the skin. After the incisions have been made, any tiny line of skin attached to the vermilion near C should be carefully excised (Fig. 8-23F).

In designing and fitting the two sides together, it is better to work with them *as though working in wood, than as though they were rubber* and could be pulled, stretched and molded into position. All incisions should be sharp, clear cut, definitive ones, and when the lip is opened as in swinging the triangular flap down, the cut at the angle should be complete so that the angle can fit up snugly against B on the columellar side.

At no time during the whole operation is it desirable to grasp any of the lip, which is to be used in the repair, with forceps. The gloved fingers are used for most of the holding with a somewhat clumsy appearance, but *with improved healing and no forceps scratches*.

Angled Crile clamps which have a soft spring are used at the corners of the mouth to help control bleeding (Fig. 8-23F). Small mosquito forceps with rubber tubes over the jaws and a rubber band to close them gently may be substituted.

Closing the Lip. A and A′ are usually closed with a buried No. 000 white silk suture. If preferred, a large, firm No. 000 catgut suture is put in from the mucosal surface, picking up a good bit of tissue under both A and A′ and thus *in one move elevating the ala and closing the lip and nostril* in the desired direction (Fig. 8-23G).

B and B′ are closed with another fine buried silk suture and with a fine surface suture. C and C′ are fitted together to test the design. An excision is then made so that a V is cut out of the cleft side's vermilion just lateral to C′, opening the area and dropping a V-shaped flap of the vermilion down. This is sometimes accomplished by a single appropriate incision, simply opening the area, but this gets into the rubber idea and the wood-working technic usually is best (Fig. 8-23G).

On the sound side (after being doubly sure remnants of white skin are off of the vermilion flap below C) the largest sacrifice of tissue is made. The rather long flap of *vermilion is fitted across into the open vermilion cut* on the cleft side and the excess is cut off. For the incisions and trimming in this region, a fine, very sharp scissors is most useful (Fig 8-23H).

C and C′ are closed with a fine surface stitch. Further surface closures are usually done between AA′, BB′ and CC′, using fine black silk. The vermilion flaps are closed with fine surface sutures, usually anchoring the points of the flaps first. Mucosal closure is continued by going right on around the vermilion clear up the inside to the buccal fornix and being sure to close the mucosa entirely even if it rests on a raw surface of the premaxilla (Fig. 8-23H, I).

This mucosal closure is almost as important as the skin closure. It closes the entire lip for best primary healing and thrusts the lip forward *as no* other part of the operation does, by being sure there is a free loose amount of tissue below even if the upper end is tighter (Fig. 8-23J). If this end of

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Due to the curvature of the surface of the lip, one is measuring "air distances" rather than "ground distances" in locating all of these points. This would seem to be a source of error, but in practice these inequalities usually cancel each other.

The Operation. After one is satisfied with the marking, the lines A–B–C and A′–B′–C′ are lightly incised with a knife (Fig. 8-23D through J). The mucosa is also divided from the skin above A up in the nostril. The incision on the other side from C′ is carried upward into the nostril along the mucocutaneous junction. A rectangular skin flap is thus outlined between C′ and A′ and may be used later, if necessary, to form the nostril floor by rotating it 180 degrees up into place (Fig. 8-23C).

Mobilizing the Lip and Nose. An incision is made in the buccal fornix on the cleft side, extending from the molar region forward to the cleft (Fig. 8-23D). The soft tissues of the cheek are elevated carefully from the bone up toward the orbital border. This freeing of the cheek should allow that side of the lip to be brought easily across the cleft and the nostril to be rotated into its proper position. If tightness of the lining of the nose prevents this, it may be necessary to make a small vertical incision in front of the anterior end of the inferior turbinate (Fig. 8-23E). After the lip and ala are freely mobilized, small scissors are introduced through the buccal fornix and the skin of the nose is elevated throughout the lower half and over across the midline toward the normal side (Fig. 8-23E). This tends to minimize corrugation of the lining when the nostril is rotated inward and up to its new position, and possibly helps establish a columellar-alar angle instead of the straight line that is present here in wide clefts. The undermined cheek is packed temporarily with one-fourth strength adrenalin on gauze.

Similar mobilization of the lip (but not the nose) is done on the opposite side, though it is usually not so extensive. If the nose is badly deviated, it may be necessary to elevate the base of the normal ala up out of the pyriform recess with a small periosteal elevator. Sometimes it may also be necessary to make a small cut across the base of the septum underneath

done in the presence of jaundice, or in premature or other babies weighing less than seven pounds until they have attained that weight. Upper respiratory infections are an obvious contraindication as are any pustular skin eruptions, but small areas of uninfected miliaria or heat rash are not.

None of these children should undergo operation immediately following a trip, but they should *be under observation for 24 to 48 hours for rest and* to be sure that they have not contracted any upper respiratory infection.

Fig. 8-21. Repair of wide single cleft by method described. Note the normal appearing forward thrust of the lower border of the lip and the good rotation of the cleft nostril. (From Brown and McDowell: *Surg., Gynec. & Obst.*, 80:12, 1945.)

It is still an open question as to whether these patients might not attain better general facial development if the lip and palate closures were delayed until puberty, but other factors make this choice untenable. However, this is not emergency surgery and should never be done under any except the most favorable conditions. A delay of one month seldom will do much harm, while a satisfactory repair may be of inestimable value to the child and conversely a faulty repair may cause irreparable damage.

Feeding is always a problem in these infants and, especially if the palate is open, they are seldom able to nurse from the breast. However, it is rarely necessary to gavage them. They can be fed breast milk or a suitable formula with a medicine dropper or a syringe, best given with the baby held almost in a sitting position and taking from 30 to 40 minutes for each feeding rather than the usual 15 to 20 minutes.

Postoperative Care. No dressing is applied over the suture line when good nursing care is available. The nurses are instructed to clean the suture line with alkaline antiseptic solution on tiny gauze pledgets every few minutes for the first hour after operation and then every hour for the remainder of the day. After this, the lip is cleansed after each feeding and at other times when necessary to prevent the formation of any clots of blood or serum around the stitches. If experienced nursing care is not avail-

the wound seems too tight, it is loosened by vertical mucosal cuts on either side from the fornix downward. This is one of the few places in plastic surgery in which cutting one way and sewing another gives much help. But here the soft mucosa can actually be transposed in position from a tight purse string in the fornix to rather free flaps of mucosa that can be advanced into the lip. Complete closure of the mucosa also prevents adhesion of the lip to a raw premaxilla from occurring (Fig. 8-23I, J).

This point of mucosal closure is dealt with at length because it is the point most responsible for kicking the lip out forward. The fine mucosal sutures put the lip where it can best stay itself. Gross stay sutures may crowd the lip forward but they will not permanently hold the tissue in place. Protrusion of the lip should be accomplished before stay sutures are put in.

Stay sutures of B black silk are put in from the mucous surface if desired, going through the lip almost to the skin, usually one or two in number.

The floor of the nose is closed with surface sutures on a small full curved needle, using the flap freed on the columellar side and any part necessary of the flap left from the incision on the cleft side. Care must be taken not to include any vermilion in the floor of the nostril where it could be seen.

The nostril can be somewhat shaped by mattress sutures through it from the skin surface to pick up the mucosa, these two surfaces having been separated during the dissection. One or two are put in the alar fold, one higher up on the ala and one to try to help form an angle at the columellar-alar junction. These sutures are not very important and can be omitted (Fig. 8-23H).

Many operators use a mattress suture from the alar fold across the floor to tie inside the sound nostril against the septum, using small plates inside and out to prevent cutting of the sutures. If the lip is otherwise solidly closed, one can omit this suture.

The nostril is gently packed with greased gauze and a Logan bow used if desired.

At the end of the operation, the lip should be full and in front of the lower (Fig. 8-23J). A good flexion crease should be present. The lip should have good width and not be too long. The nostril should have a good floor, the ala should point toward the columella and the level of the ala should be the same or a little higher than the opposite one (Figs. 8-24, 8-25 and 8-26).

Preoperative Determinations and Care. Single clefts can be repaired at any time, but are preferably closed early in life. An early closure facilitates feeding, eliminates the necessity for constant apologies and explanations to friends by the parents, and the elastic pressure of the closed lip tends to narrow the anterior portion of any associated palate cleft during the first year of life. Even very young babies, if they are well developed, tolerate the operation well, and closures have been done as early as the age of seven hours. Quite often, the father wishes to have the cleft closed before the mother sees the baby and this may be done, but one parent should see the baby beforehand. If the patient is first seen at the age of three or four days when he is losing weight, one might as well wait until he has regained his birth weight before undertaking the repair. The closure should not be

Fig 8-26 Preliminary set-back of the premaxilla when absolutely necessary for closure of the lip or to prevent crumpling of the septum with subsequent blockage of the nasal airways. A small block of bone is resected submucously from the vomer just back of the premaxilla, and the latter is set back in contact with the vomer (like closing a drawer) Immobilization is obtained by nailing a straight Keith needle through the center of the premaxilla and on back longitudinally through the vomer. (From Brown, McDowell and Byars Surg., Gynec. & Obst., 85:20, 1947.)

Fig 8-25. Some of the common variations in size, shape and position of premaxillae in double cleft lips (From Brown and McDowell Surg, Gynec & Obst, 85 20, 1947.)

of tooth buds it contains (Fig. 8-25). The large oval, or almost rectangular, premaxilla forms a better central segment of the jaw, supports the lip better, and will have the lateral incisor tooth buds inclined only slightly laterally, so that it is easier to work with for both the surgeon and the orthodontist. It overlaps the lateral processes slightly on both sides, so that if it is necessary to set it back, it will rest as a bridge on them and will not tend to tilt and cannot sink back behind them. The small, round, premaxilla may be smaller than the hiatus between the two lateral processes, so that one must try to prevent it from being forced back between and behind them, thus producing a retruded upper jaw and lip. The tooth buds are arranged in a partial circle around its periphery so that the lateral incisors may tend to grow directly into the lateral processes, or even up into the nostril floors, or forward through the lip if it becomes tilted. Some of the permanent tooth buds may be entirely missing from these tiny, round, premaxillae. Thus, the size and shape of the premaxilla greatly influences the final result.

In the newborn baby, the premaxilla is nearly always anterior to the lateral processes. It may be anywhere from just in front of them to extreme positions out on the tip of the nose where it may project forward and upward like a snout. In addition to forward displacement, it may be tilted from side to side, or rotated. If the cleft is partially fused on one side, the premaxilla may be rotated toward that side, but tilted so the open edge is farther forward.

It is not uncommon to find a bend or kink in the septum just behind the premaxilla, sometimes so marked as to occlude one or both nasal airways at birth. This may be the result of intrauterine pressure on the premaxilla.

As a rule, the premaxilla is not disturbed or set back if the lip can be closed with it in its original position unless: 1, it is badly tilted or rotated; or 2, it is so far forward that the elastic pressure of the closed lip might bend the septum and occlude one or both nasal airways.

If the premaxilla is to be set back, it is set back the least possible amount necessary to allow successful closure of the lip. This is done by splitting the mucosa over the bottom of the vomer and resecting a block (submucously) of the vomer just back of the premaxilla. The premaxilla is set back until it is in contact with the vomer again and immobilized by a wire suture through both fragments or better by nailing a straight Keith needle directly backward through the center of the premaxilla and on back through the center of the vomer (Fig. 8-26). In setting the premaxilla back, an attempt is made to correct any rotation or tilting so that it will be centered with respect to the lateral processes as well as possible. This is insured somewhat by having excised a block rather than a wedge of the vomer.

When the premaxilla is larger than the space between the two lateral processes, and good firm immobilization is obtained, the lip can be closed during the same operation, otherwise, the closure is done about two weeks later. Bony union between the premaxilla and vomer is rarely obtained either way, but the fibrous union helps a good deal in keeping it centered.

The Disposition of the Prolabium. The prolabium is the central segment of the lip and must be used in this position in the closure. The upper part of it is sometimes advanced secondarily into the columella at three or four years of age, but it is best not to do this primarily.

able, the suture line can be covered with a fine mesh grease gauze dressing which may be changed daily or oftener, cleansing the lip each time.

The grease-gauze pack in the nostril is removed in 48 hours, and the skin sutures on the lip are taken out on the fourth or fifth day. The Logan bow can be removed after one week and remaining inside sutures after 10 days

Feedings are usually given with a syringe until 7 to 10 days after operation, after which the baby may nurse from a bottle if the holes in the nipple are burned out and enlarged. If the baby is breast fed, the breast milk is usually given with a syringe for three or four days after operation and then the baby is allowed to nurse if the palate will permit it.

The patient is usually discharged from the hospital on the tenth postoperative day, with the lip healed, all sutures out, no dressings, and able to nurse from a bottle or the breast, as far as the lip is concerned.

The cooperation and help of a pediatrician throughout the baby's hospitalization is solicited and gratefully received.

REPAIR OF DOUBLE CLEFT LIPS

The surgical repair of double cleft lips is about twice as difficult as in single clefts and the results are about half as good.

Normally, the frontonasal process of the embryo fuses with the two lateral maxillary processes by the ninth week. When there is total lack of fusion of these on both sides, the three processes develop independently of each other from the ninth week until term, with the result that the baby has not only a hiatus or cleft on either side, but also has severe growth distortions of the entire middle third of the face. Partial fusion on one side makes this distortion asymmetrical on the two sides and may render the interpretation and plan for repair even more difficult.

The double clefts vary a great deal in the amount and shape of the deformity, so that individual study and improving is necessary in planning their repair. They are not considered surgically simply as two single clefts, both of which happen to occur in the same patient.

Age for Primary Operation. A fairly satisfactory rule is to close them as soon as possible after the baby weighs 10 pounds, subject to variations in the extent of the deformity and the child's general physical condition. Many of these patients have an anemia and are given transfusions to bring the preoperative hemoglobin up to 12 to 15 grams per 100 ml. Nearly all of those with open palates will have a chronic otitis media which is not an especial contraindication to surgery. Operations are not done, of course, during an acute exacerbation.

Until the lip is closed, feeding is done with a syringe (with a short piece of rubber tubing attached) and gavaging is usually avoided.

Treatment of the Premaxilla. The premaxilla is the separate central segment of the upper jaw and is that portion arising from the embryonic frontonasal process. Briefly, the problem of the premaxilla is that it is nearly always too far forward in the newborn baby, but only with considerable effort can it be kept from being retruded too far backward in the adult. It varies a good deal in size, shape, and position, and at times, as to the number

of tooth buds it contains (Fig. 8-25). The large oval, or almost rectangular, premaxilla forms a better central segment of the jaw, supports the lip better, and will have the lateral incisor tooth buds inclined only slightly laterally, so that it is easier to work with for both the surgeon and the orthodontist. It overlaps the lateral processes slightly on both sides, so that if it is necessary to set it back, it will rest as a bridge on them and will not tend to tilt and cannot sink back behind them. The small, round, premaxilla may be smaller than the hiatus between the two lateral processes, so that one must try to prevent it from being forced back between and behind them, thus producing a retruded upper jaw and lip. The tooth buds are arranged in a partial circle around its periphery so that the lateral incisors may tend to grow directly into the lateral processes, or even up into the nostril floors, or forward through the lip if it becomes tilted. Some of the permanent tooth buds may be entirely missing from these tiny, round, premaxillae. Thus, the size and shape of the premaxilla greatly influences the final result.

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When the premaxilla is larger than the space between the two lateral processes, and good firm immobilization is obtained, the lip can be closed during the same operation, otherwise, the closure is done about two weeks later. Bony union between the premaxilla and vomer is rarely obtained either way, but the fibrous union helps a good deal in keeping it centered.

The Disposition of the Prolabium. The prolabium is the central segment of the lip and must be used in this position in the closure. The upper part of it is sometimes advanced secondarily into the columella at three or four years of age, but it is best not to do this primarily.

Many plans of closure have included the vermilion of the prolabium in the vermilion of the reconstructed lip, but these nearly always result in a double notch. This notching is not easy to eliminate by secondary procedures as it is due to an inherent thinning and upward direction of the vermilion on both sides of the prolabium.

Consideration of the "cupid's bow" configuration of some normal lips has somewhat confused this issue. The occurrence of the cupid's bow varies a good deal in normal lips and in any event it is an upward prolongation of the *upper* edge of the vermilion beneath each philtrum. The lower edge of the normal vermilion has a gradual downward curve from the center outward without any upward notches, and it is almost impossible to get this when the thin U-shaped vermilion of the prolabium is used as the central portion of the new lip.

It is thought best to use a plan in which an incision is made at the mucocutaneous junction all the way around the prolabium and its vermilion is turned back as a flap to be used for lining if necessary.

Design for Closure. Many of the features of the modified Mirault operation for single cleft lips are used in closing the double cleft lips. Usually a flap is turned down from the inner surface of the lateral border of the cleft on each side, and they are brought together in the midline beneath the prolabium (Fig. 8-27A). If the cleft is partial on one side and total on the other side a V-excision operation may be used on the partial side and a Mirault flap on the total side (Fig. 8-27B). When the prolabium is unusually large and long, so that the Mirault flaps under it might result in too long a lip, 2 or 3 millimeters of skin can be excised from the bottom of the prolabium to shorten it. If the prolabium is tiny, the lateral flaps may be designed in a rectangle (rather than a triangle) to elongate the lip (Fig. 8-28), but this is rarely advisable.

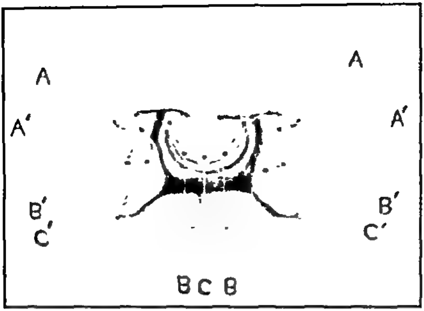
In marking out symmetrical clefts with the columella in the midline, a transverse line is imagined across the prolabium at the level of the base of the columella, and the points A are marked on either side where this line crosses the mucocutaneous junction A′ is marked just inside the lower point of the nostril rim on each lateral side of the cleft, being careful to place it in such position that a good nostril will be formed when A′ is approximated to A, and marking it symmetrically on the two sides (Fig. 8-27A).

The point C is at the bottom of the skin of the prolabium in the midline and equidistant from the two A points. B is one third of the distance from C back to A on the curved lower border of the skin of the prolabium on either side.

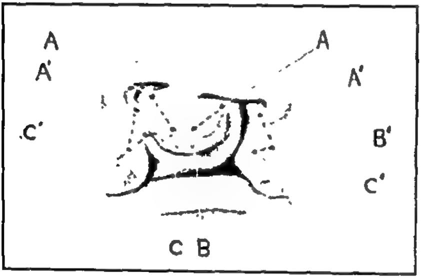
C′ is on the mucocutaneous line of the lateral part of the lip and is opposite the most medial point where there is still full thickness of the vermilion.

To locate B′, the straight line distance AB is measured with small calipers. One point of the calipers is then set on A′ and the calipers rotated until the other point is BC distance from C′.

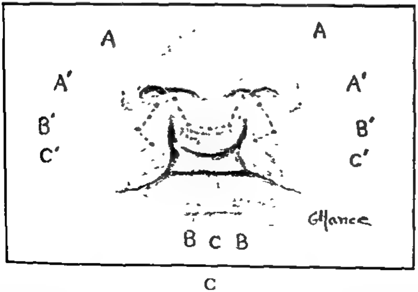
The above can be considered as a standard marking and can be altered when necessary. For instance, when the cleft is partial on one side, the line A′–B′–C′ is sometimes a straight one, so that B′ can be omitted and a



A



B



C

Fig 8-27. A, closure of total double cleft with Mirault flap from each side. B, closure of totally cleft side with Mirault flap and partially cleft side by V-excision plan C, closure of double partially cleft lip with Mirault flap from each side See text for details. (From Brown, McDowell and Byars Surg., Gynec & Obst., 85 20, 1947)

straight incision made from A′ to C′ and a V closure done on that side (Fig. 8-27B).

The Closure. The above points are punctured in and the lines scratched in with 5 per cent alcoholic methylene blue, using a fine mechanical drawing pen. The lines are then lightly incised with a knife, with care not to cut the points out. An incision is then made in the buccal fornix on each side and carried upward to separate the lip from the upper jaw (Fig. 8-29). This undermining is carried upward almost to the orbital border until the cheek is separated from the underlying facial bones, and the space between them is packed temporarily with gauze soaked in 1:5,000 adrenalin solution.

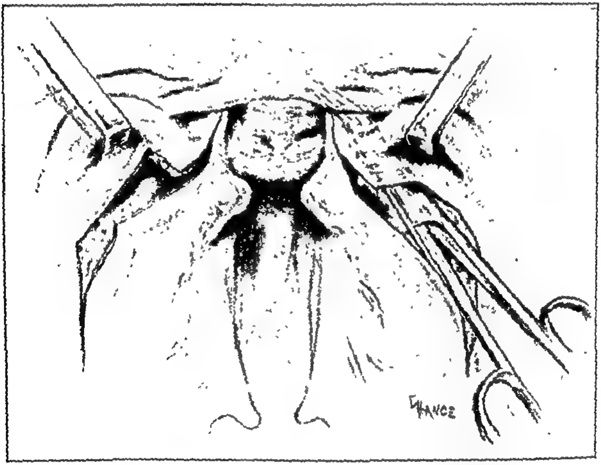


Fig. 8-28 Undermining to separate soft tissues of cheek from facial bones and to separate lining from covering of nostril. See text for details (From Brown and McDowell. Surg., Gynec. & Obst., 85 20, 1947)

The buccal fornix incision is then carried upward inside the lateral wall of the nostril to divide the mucosa between the upper and lower lateral cartilages of the nose until the nostril can be rotated into position and A′ can be brought over to A without tension. A small fine scissors is introduced through the buccal fornix and the lower lateral cartilage of the nostril is separated from the skin covering by alternate spreading and dissecting up to the midline (Fig. 8-27).

The lines A′–B′–C′ are then incised through the full thickness of the lip, a stab blade knife being used with a perpendicular sawing motion (Fig. 8-30). The small flap A′–B′–C′ is rotated 180 degrees into the nostril floor.

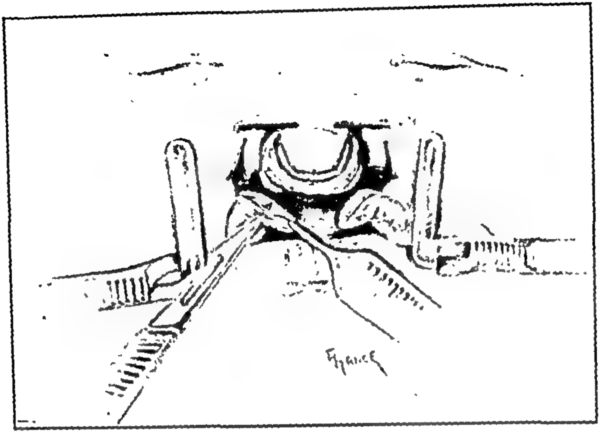


Fig 8-29 Top, perpendicular opening incisions through the lip. Knife is trimming off tiny remnant of attached skin from vermilion flap. Note vermilion of prolabium turned back for lining. Bottom, final plan of closure with tiny 0000000 black silk sutures (From Brown and McDowell. Surg, Gynec & Obst, 85 20, 1947)

The vermilion of the prolabium is turned backward as a flap to use for lining and A–A′ and B–B′ are approximated on both sides. No. 000 white silk sutures being used subcutaneously and No. 0000000 black silk sutures in the skin. C′–C′ are approximated directly under C and fine interrupted black silk skin sutures are placed all along between A–B–C. The vermilion

closure is done by interdigitating zigzig flaps from the two sides. The inside mucosa from the two sides is sutured to the prolabium vermilion which was turned back. The nostril floor flaps are trimmed and sutured to the portion of the prolabial skin inside the nostrils, and mattress sutures are put through the nostril walls to aid in shaping them. Stay sutures may be put clear across the lip from the inside, encompassing the full thickness of the lip except the skin, to avoid any visible suture marks on the outside. (The type described by Lane is a good one.)

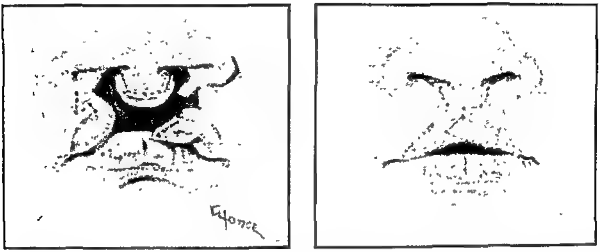


Fig. 8-30 Plan utilizing rectangular flaps rarely used and then only for very tiny prolabium as this plan elongates the lip (From Brown and McDowell. Surg., Gynec. & Obst., 85:20, 1947.)

A Logan bow is strapped to the cheeks to protect the lip and take tension off of it while crying, and the nurses keep the suture lines free of crusts by frequent cleansing. The skin sutures are left in five days and the others a few days longer. The baby can usually be fed with a bottle after the first week, if the holes in the nipple are enlarged, and the child is discharged from the hospital after all sutures are out.

Any surgery on the palate is delayed until about 18 months of age to permit the tooth buds to migrate out of the palate into the alveolus.

The possibility of secondary procedures on the lip is considered from the beginning with the parents, but they will be fewer in number and less in extent if the primary closure is a good one.

Those children who are born with a total double cleft and almost no columella will frequently require a secondary elongation of the latter so that this may be considered standard in this type of patient. Further elevation of the nose may be obtained, when desirable, by an L-shaped cartilage transplant.

Maintenance of the size and structure of the upper dental arch is important in these patients for lip support as well as for other reasons. The child's dentist is contacted early so that proper dental hygiene may be instituted, and he may help later in providing or securing adequate orthodontic care. Limited prosthodontia may eventually be necessary in patients with total clefts.

In addition to dental care, those children who have associated palate clefts may require the assistance of speech therapists and otolaryngologists.

Tonsillectomies and adenoidectomies should not be done routinely, but they may be carried out if necessary for reasons of general health, or especially if the tonsils and adenoids are contributing to any loss of hearing. As the quality of the surgical reconstructions of these lips and palates improves, the need for these ancillary services decreases markedly—often to the point where only a little limited orthodontia is required. Prosthodontia is seldom required and speech training decreases in amount and incidence.

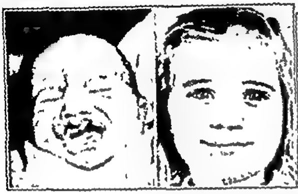


Fig 8-31 Partial double cleft shown just before operation (age 2 days) and at age of 3 years. Closed with small Mirault flap from each side. Good full vermilion obtained (From Brown, McDowell and Byars Surg., Gynec. & Obst., 85:20, 1947.)

Fig 8-32 Total cleft on one side and partial on other. Closed with Mirault flap on total side and V-excision operation on partial side (all in one operation at age of a few days). The premaxilla was not moved, except by the elastic pressure of the lip. A good deal of rotation of the left nostril was necessary to get symmetry (From Brown, McDowell and Byars. Surg., Gynec. & Obst., 85:20, 1947.)

Fig 8-33. Total double cleft with almost no columella and with premaxilla projecting forward from tip of nose. Premaxilla set back and lip closed early in life and columella elongated at age of 3½ years by method shown Upper lip maintained in front of the lower one and patient has perfect speech following closure of palate at age of 18 months. (From Brown, McDowell and Byars Surg., Gynec & Obst., 85:20, 1947.)

The plastic surgeon can render an additional service if he will examine these patients each year throughout the growing period and advise the parents in regard to these problems as they arise. Though starting with a severe initial handicap, these children often prove to be brighter than average and succeed so well in later life that one feels well repaid for the extra time and effort required in providing the best possible care for them (Figs. 8-31, 8-32, and 8-33).

CLOSURE OF CLEFT PALATE

Cleft palates are preferably closed after the tooth buds have migrated out of the palate (12 to 14 months) and before any definite speech habits have been formed (two years). Sixteen to 18 months of age is often a good time for the closure.

As with cleft lips, chronic otitis media is not a contraindication to operation, but acute exacerbations are. Particular attention should be paid to the preoperative hemoglobin level as these children often have nutritional anemias, and preoperative transfusions are usually given when it is low. These children should come to the operating room in a well hydrated condition.

The prevention of operative mortalities consists of preventing shock (preoperative and postoperative blood transfusions and intravenous fluids as necessary), maintenance of the airways during the operation, and maintenance of light anesthesia during the operation.

Anesthesia and Maintenance of Airways. Perhaps in no other operation is such close teamwork necessary between the surgeon and anesthetist. The anesthetist must keep the plane of anesthesia light so that the cough reflex is not lost, but so level that the child does not gag excessively and does not vomit. The surgeon must listen to each respiration throughout the operation and suction the throat or pull the tongue forward at any time if the exchange is not free and easy. These children must not be struggling for air at any time during the operation. Even slight cyanosis or enlargement of the pupils demands that the airways be cleared immediately and the anesthesia lightened. Attention to these details means the difference between an excessive mortality rate and one that is almost nil.

Induction is with drop ether and as soon as the correct light plane of anesthesia is reached, it is maintained by endopharyngeal insufflation of oxygen-ether, with a soft rubber catheter inserted through the nose on the uncleft side with the tip of it at the level of the epiglottis.

The surgeon sits at the head of the table, working upside down, with the first assistant on the right and the second assistant on the left. The child's head is extended back and is slightly dependent, placing folded sheets under the scapulae and buttocks if necessary to maintain this position. The position is important so that any blood or saliva will run up into the nasopharynx rather than down into the larynx. The second assistant steadies the head in this position with one hand and passes instruments with the other. The first assistant holds the tongue suture in one hand and uses the suction with the other to keep the airways clear at all times. The mouth is kept open with a Lane gag, but never pried so far open as to embarrass the respiratory exchange. Children over three or four years of age are most easily done under endotracheal anesthesia with the throat well packed; endotracheal anesthesia in small babies, however, may be followed by a too high incidence of postoperative croup and laryngeal edema and obstruction.

The Operation. The initial incision is made with a No 15 blade, starting over the ramus of the mandible and coming forward between the hamulus and maxillary tubercle with the blade vertically placed. The incision is then carried forward on the inside of the alveolus, turning the blade horizontally

so as to cut against the alveolus, to within 1 to 2 cm. of the alveolar cleft (Fig. 8-34A).

A right-angled Blair-Brown palate elevator is introduced in the anterior end of the incision and the soft tissues overlying the palatine bone elevated medially to the cleft and posteriorly as far as the major (posterior) palatine artery (Fig. 8-34C). A Joseph nasal periosteal elevator is then introduced into the incision just back of the maxillary tubercle, pushed medially against the hamulus, or levered against it, to fracture the hamulus off medially and allow the tensor tendon to slip off of it (or the tensor tendon is cut if this is not possible). It is impossible to do one of these operations without a detailed knowledge of the anatomy of the palate, especially the triangular relationship between the maxillary tubercle, the hamulus, and the foramen for the artery.

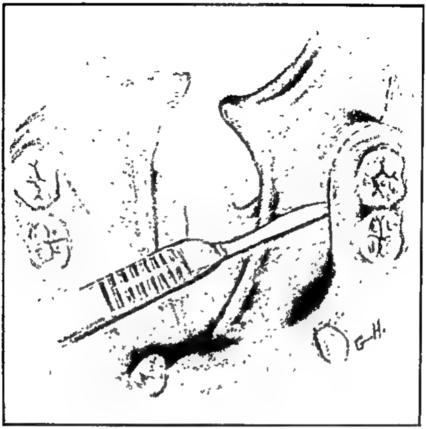
The right-angled Blair-Brown elevator is then inserted posterior to the artery and hooked around it until the anterior edge of the blade comes up on the posterior edge of the palatine bone, getting complete mobilization of the palate all around the artery and stretching the artery out of its foramen (Fig. 8-34D). The lateral wound is then temporarily packed with gauze soaked in 1:5,000 adrenalin and the palate is mobilized in the same manner on the opposite side.

With a long single hook, and a No. 11 blade knife, the oral and nasal mucosa are split apart at the end of the cleft on either side from the alveolus in front to the tip of the uvula behind (Fig. 8-34B). The nasal mucosa is then elevated from the septum on the uncleft side, and the palatine bone on the cleft side, until it can be rolled into a tube to line the nasal airway. It is sutured in this tubular position, using interrupted stitches of 00 chromic catgut on small Lane cleft palate needles, with the knots tied on the nasal surface. This is continued on back through the soft palate, uniting the two sides of nasal mucosa flatly instead of in a tube here (Fig. 8-34H), and cutting the aponeurosis on one side if necessary to get enough mobilization (Fig. 8-34E).

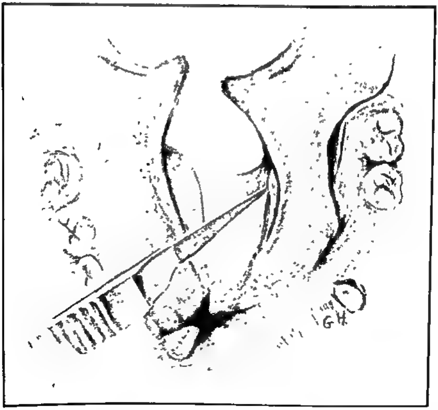
One or two stay sutures are placed across the middle of the palate, being sure to get one of them opposite the hamular processes. These are of B silk on a large Lane cleft palate needle and are put in as horizontal mattress sutures, encompassing the entire thickness of the palate except the nasal mucosa. They are put in about 1 cm. from the cleft on either side, and are not tied, but have mosquito clamps hanging on them. The weight of the clamp should be sufficient to approximate the edges, a good test to see if the palate is adequately mobilized.

The oral mucosa is then closed with vertical mattress sutures (Fig. 8-34I, J, L) of horsehair or single strand nylon, with a few interspersed plain over sutures to get good approximation of the edges and to close the uvula, where there is not enough room for mattress sutures.

The elastic pressure of the closed lip during the first year or two of life will do a great deal to narrow the alveolar cleft anteriorly. However, it is in this area that the greatest difficulty will be encountered. Small flaps of mucosa are raised from the surface of the cleft to line the nasal airway, and from the under surface of the lip and outer surface of the alveolus to close the oral side. Under no circumstances should the alveolus be chiseled, drilled, or wired, as this might damage permanent tooth buds.

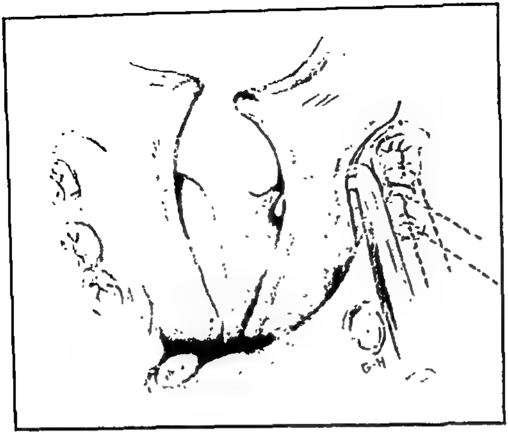


A



B

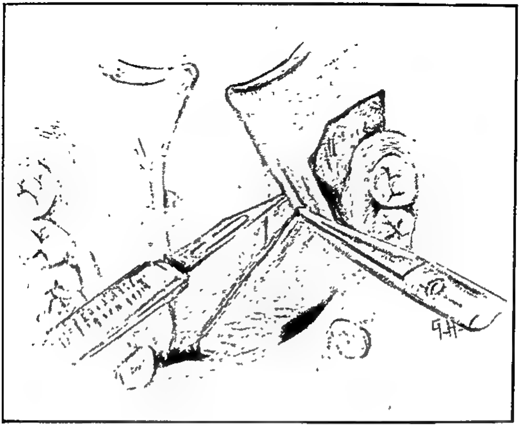
Fig. 8-34 Standard Dieffenbach-Warren operation for single cleft palate. A, initial opening incision from ramus to maxillary tubercle, around it, and forward on the inside of the alveolus B, splitting the nasal from the oral mucosa at the edge of the cleft all around. (From Blair and Brown. Surg., Gynec. & Obst., 59:309, 19



C

D

Fig 8-34 (cont.) C, right angled elevator introduced into lateral incision to elevate mucoperiosteal layer from bone in front of the major palatine artery D, same elevator in lateral incision behind the artery and hooking around it up on to the posterior edge of the palatine bone. (From Blair and Brown Surg, Gynec. & Obst, 59.309, 1934)



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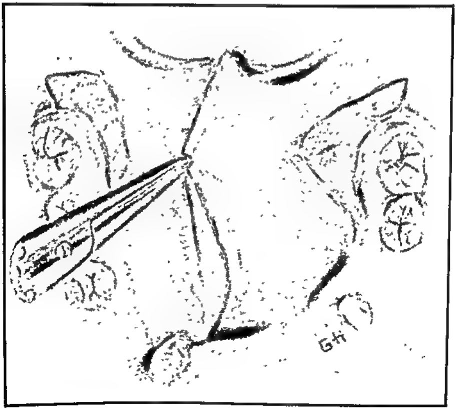
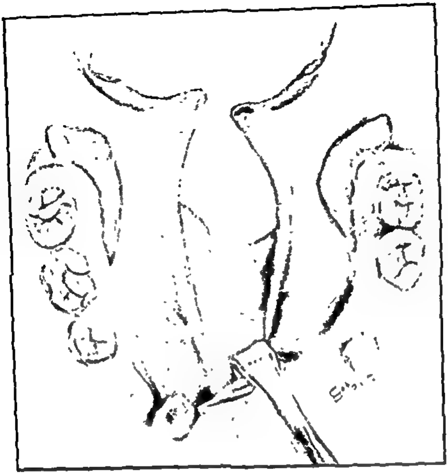


F

Fig. 8-34 (cont.) E, dividing the aponeurosis on one side when necessary. F, testing mobility of the flap. (From Blair and Brown Surg., Gynec. & Obst, 59.309, 1934.)



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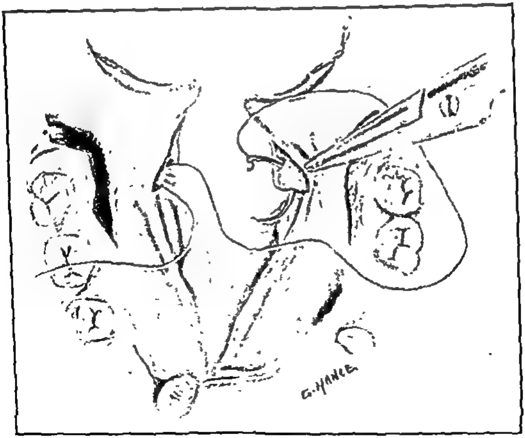
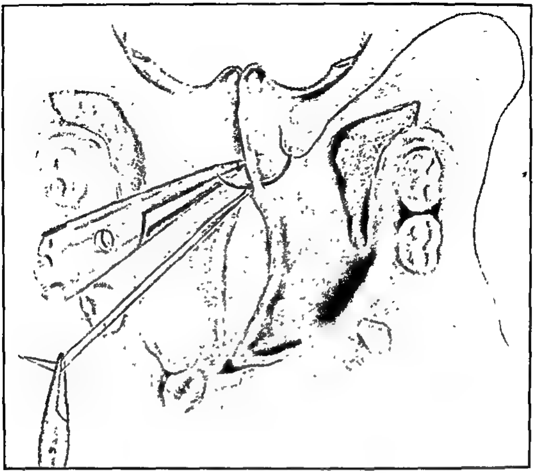
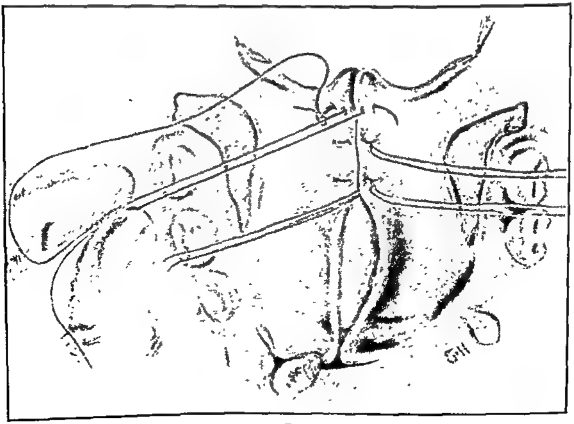


H

Fig 8-34 (cont) G, separating the nasal mucosa from the palatine bone in front H, suturing the nasal mucosa of the soft palate (using fine catgut with the knots tied on the nasal surface). (From Blair and Brown Surg, Gynec. & Obst, 59:309, 1934)

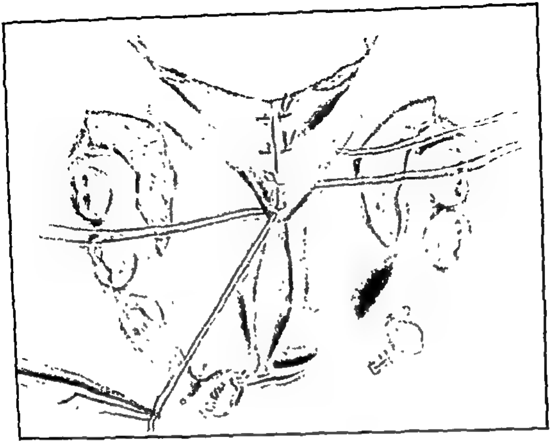


I



J

Fig. 8-34 (cont.) I, closing the oral mucosa with vertical mattress sutures of nonabsorbable material. J, continuing this closure. (From Blair and Brown. Surg., Gynec. & Ob 59 309, 1934.)



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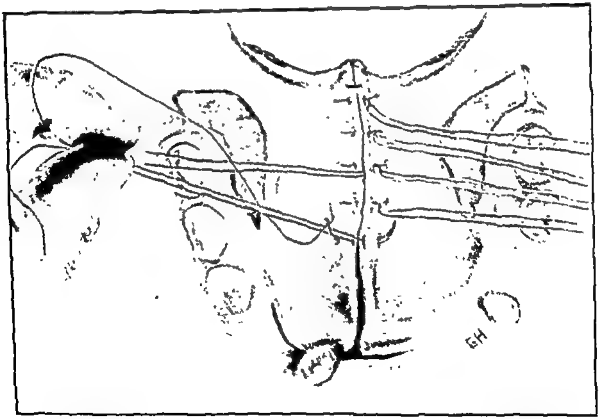
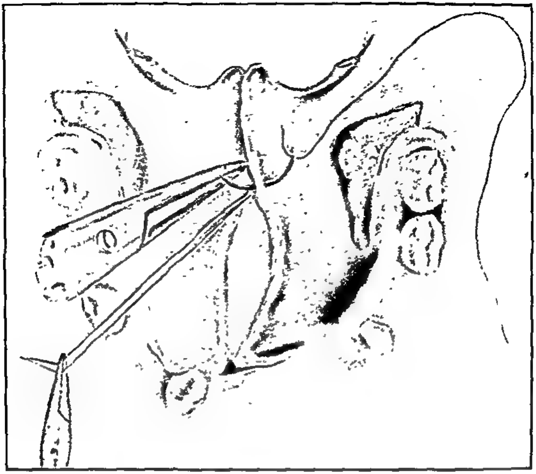
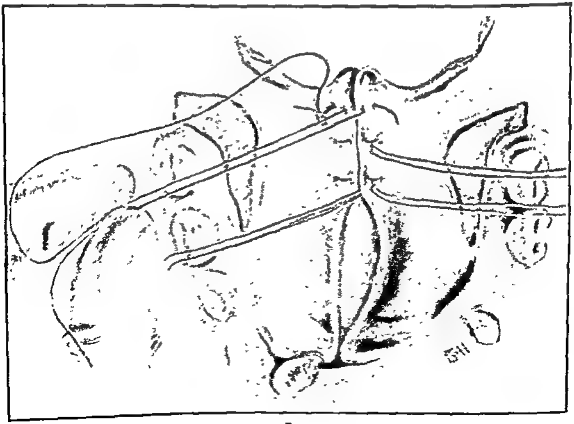


L

Fig 8-34 (cont.) K, pulling the uvula forward to suture the nasal mucosa together at the tip end of the soft palate L, the vertical mattress sutures are continued forward to the alveolus to complete the closure, and small iodoform-balsam of Peru packs are inserted into the lateral incisions for 48 hours (From Blair and Brown. Surg, Gynec. & Obst., 59.309, 1934.)



I



J

Fig. 8-34 (cont.). I, closing the oral mucosa with vertical mattress sutures of nonabsorbable material. J, continuing this closure. (From Blair and Brown. Surg., Gynec. & Ob. 59:309. 1934.)

backward and still having the bony palate in front to separate the nose and mouth.

The principle is that a direct flap of practically the entire palate is raised completely from the bone and is immediately set back so that the anterior free edge is anchored clear back at the posterior edge of the bone. The major palatine arteries are definitely preserved and left to supply the palate flap. The palate may be allowed to heal here, the bony palate to cover completely with epithelium, and, at a second operation, the palate cleft itself closed, or both closure and elongation may be done at the same operation.

The Operation. An incision is made across the surface of the anterior pillar, over the ramus and onto the maxillary tubercle; it is then carried entirely around the palate against the alveolus and out over the opposite side (Fig. 8-35A).

An elevator is used to detach the mucoperiosteum completely from the bone, and the arteries are carefully preserved. When the posterior edge of the bone is reached, the nasal mucosa is carefully opened and a narrow edge is left attached to the bone to be used for the anchoring sutures that are put in later (Fig. 8-35B). The elevator is put behind the arteries and the space down to the hamulus and pterygoid plate is opened so that the surface and deep soft tissues throughout the entire extent of the incision may be freely mobilized. The tensor muscle may be divided at the hamulus, or the hamulus fractured over medially, and the dissection of the aponeurosis from the posterior edge of the bone is completed so that the entire mass of palate tissue is held by the remaining uncut surface over the pillars, the major arteries and the levators. At this stage, in spite of the very free dissection, it is interesting to note that the levators are still active (Fig. 8-35C).

The arteries are then elongated by carefully stretching them from their foramina and slightly separating them from the raw surface of the palate. We are convinced that this procedure can be successfully carried out as we do it routinely, and we do practically the same thing in repairing total clefts.

The cleft in the palate is closed by simply freshening the edges and suturing them in layers with catgut sutures on the nasal surface and vertical mattress nylon or horsehair sutures on the oral surface.

The palate is elongated by setting the anterior cut edge clear back at the posterior bony edge with a horsehair or silk suture to the little flap of nasal mucosa that is left attached here. The lateral free edge of the flap is then anchored at the maxillary tubercle on each side and one or two more sutures may be inserted (Fig 8-35D).

The tissue is usually somewhat humped up, but it is definitely longer and the soft palate may be lying in contact with the posterior wall. The anterior defect is covered smoothly with a pack of balsam of Peru and iodoform gauze, and no sutures are necessary to retain it. Skin grafts can be used on the nasal surface of the palate flap, or on the oral surface of the bone, or both, but are malodorous and do not seem to contribute much to ultimate speech

Recovery is usually prompt and the patient can leave the hospital in 7 to 10 days The pack is removed about the sixth day, and repacking is occasionally necessary for bleeding.

Complete healing of epithelium over the bony palate occurs in 20 to

At the conclusion of the operation, a small iodoform-balsam of Peru gauze pack is placed in each lateral incision to control bleeding, the throat is cleared by suction, child turned over in the prone position, anesthetic tube removed, and the tongue stitch taped to the cheek or chin for possible use in the next few hours.

Postoperative Care. The child is kept in the prone position until he is well awake and has stopped bleeding. He must be constantly watched by an experienced nurse, anesthetist, or house officer during this period.

All postoperative feedings are given with cup or spoon and he is not allowed to suck on a nipple at any time. The utensils are sterilized by boiling and water can usually be started within two to three hours after operation, followed by milk in an hour or two, and thin cooked cereals and puréed foods the night of operation. These children have some difficulty in swallowing the first few hours or days, so that the intake must be closely watched and supplemented by intravenous fluids as necessary. Postoperative fever is almost always from dehydration, or a flare-up of the chronic otitis media. The otitis can be treated by chemotherapy or myringotomy as indicated.

A mild antiseptic such as 1 per cent mercurochrome can be used as nose drops and to paint the oral suture line several times daily if the child does not resist too much. Everything possible should be done to avoid excessive crying, or mechanical injury to the palate. Hard foods are avoided for one month, and the child is not allowed to put his fingers in his mouth (armcuffs) or have any toys that he might get into his mouth for the same period.

The hemoglobin is determined the next day and bolstered by transfusion if necessary. The child is kept in the hospital about 10 days. Most of the sutures will fall out during the first month, but any remaining ones can be removed after that period.

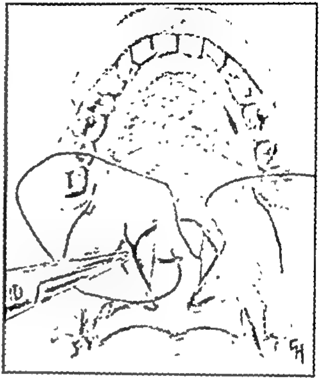
Simple speech training exercises can be started by the mother as soon as the tenderness is out of the palate, and formal speech analysis can be done, usually at the age of four or five years.

ELONGATION OF THE PARTIALLY CLEFT PALATE

In the repair of partial cleft palates one goal should be to obtain the best possible function of the soft palate. This will require pliable tissue, sufficiently long to meet the posterior wall of the pharynx (Passavant's pad) in the sphincter-like action of this region that closes the opening between the nose and throat. Although operations may be well executed and the palates may appear normal after operation, it is common to have some speech defect if the palate is just closed without elongation. This persistent speech defect is probably due to a leak of air into the nose which may occur if there is an opening left of only a millimeter or two.

Palates that are cleft only through the soft tissue or on up, part way through the bone, may have actually less tissue for repair of the soft palate than those with complete clefts, and there are also patients with uncleft palates that are so abnormally short that speech is just as bad as though the palate were cleft. Dorrance has called this "congenital insufficiency of the palate." It is in this group that the most direct attempts have been made for actually lengthening the palate, by moving the whole of the soft tissues

E



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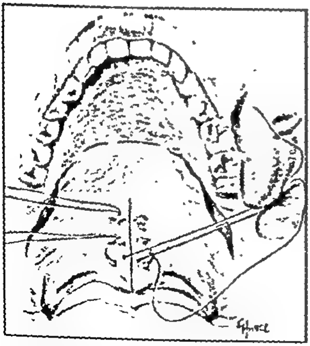

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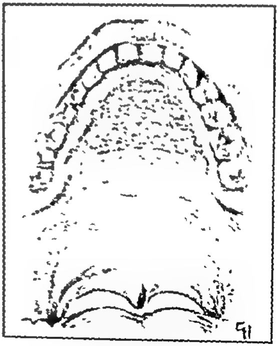
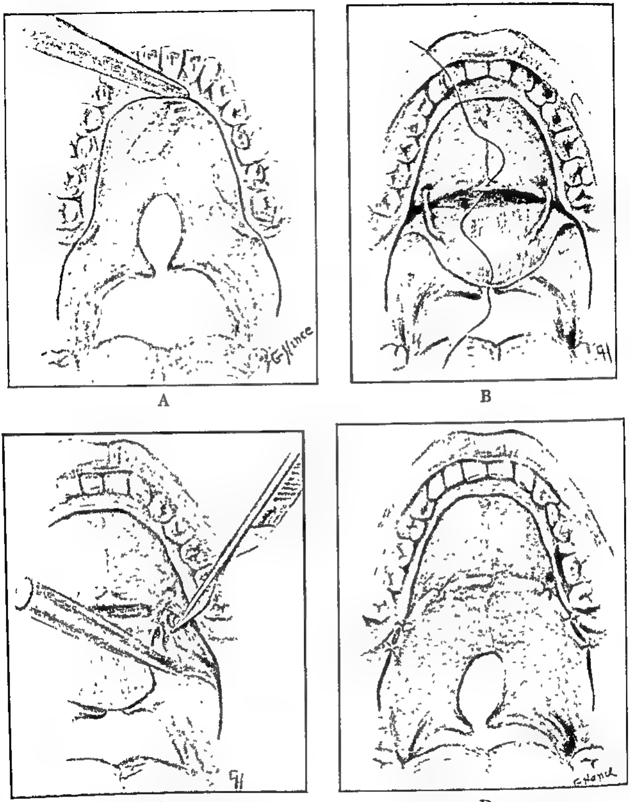


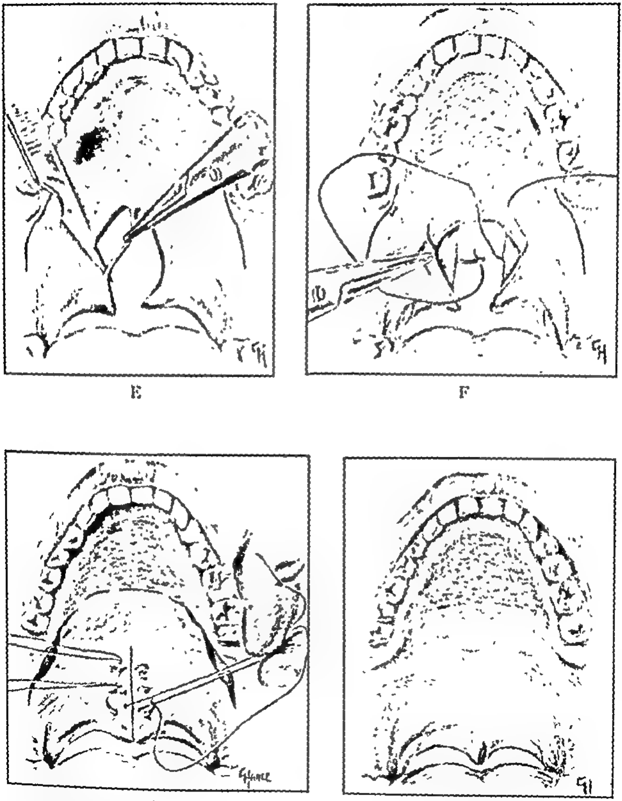
H

Fig. 8-35 (cont.) E, paring the edges of the cleft (splitting is better). F, suturing the nasal mucosa (knots tied on nasal surface). G, vertical mattress sutures in oral mucosa. H, final appearance showing closure and additional length obtained without disturbance of the levator muscle-nerve mechanism. (From Brown: Surg., Gynec. & Obst., 63:768, 1936.)



A B C D

Fig. 8-35 Elongation of partially cleft palate, showing elongation in one operation and closure later, though both procedures are generally done in one operation now. A, initial incision from the ramus forward around the maxillary tubercle and all around the inside of the alveolus, around the opposite tubercle and back onto the opposite ramus Right angle elevator introduced and entire mucoperiosteal flap raised from bones B, flap turned forward, arteries stretched out of the canals and dissected free from flap for a short distance forward The main set-back suture is inserted into the tag of nasal mucosa on the posterior edge of the bone and at the anterior edge of the flap and tied to set the entire palate back. C, showing cutting the tensor palatini tendon when it cannot be freed by fracturing the hamulus medialward. D, palate set back and held by additional sutures on either side (From Brown Surg, Gynec & Obst, 63·768, 1936.)



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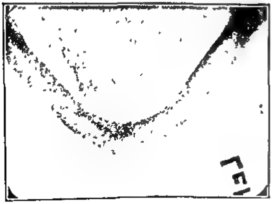
30 days, and is practically normal in appearance except that rugae are not present. At this stage the soft tissues may be somewhat humped up from side to side just behind the edge of the bone. The actual lengthening might be said to be the difference between what tissue is used in this humping up and the total distance the edge is set back. This distance may be as much as 2 cm., and is the space between the anterior incision to the posterior edge of the bone. Improvement in speech is usually already noted even though the palate is still a little swollen and tender.

A similar type of elongation can be done at a later operation on complete clefts that have been successfully closed, if care is taken to avoid puncturing the nasal mucosa while elevating the hard palate tissues.

REMOVAL OF SALIVARY DUCT STONES

Stones are much more common in the submaxillary gland and duct than in the parotid. They are usually radiopaque and may be demonstrated on occlusal films in the duct (Fig. 8-36A) and on lateral jaw films in the gland. Symptoms are obstruction and infection in the gland with pus coming from the orifice of the duct. Stones in the duct may be demonstrated on probing, and can often be palpated.



A

B

Fig. 8-36. A, submaxillary duct stone as seen on occlusal x-ray B, typical suppurative infection of submaxillary gland secondary to stone in duct

Tiny stones can often be milked out of the duct by bimanually stripping it forward and expressing them out of the orifice. Larger stones are brought to the anterior end of the duct by the same maneuver, and held in this position by an assistant while an incision is made over them and through

the orifice. As soon as the stone is extracted, the lining of the duct is sutured to the floor of the mouth to create a new and larger opening. A small blunt curet is then inserted through the duct back to the gland and any sand present removed, irrigating the duct as necessary. The patient is instructed to use natural salivary stimulants (citrus fruits, pickles, candy mints, chewing gum) for a few days to wash the gland out. If there are definite stones in the gland which cannot be expressed, removal of the gland is indicated.

Parotid duct stones can usually be seen on dental films placed between the cheek and upper gum and exposed laterally. Their removal is about the same as above, except that they are small, hard, and often stellate so that they cannot be moved in the duct. A small duct probe is usually inserted in the duct back to the stone, and dissection carried along it until the stone can be extracted. Parotid gland stones are usually small, single ones and the first symptoms may be due to a small local abscess around the stone. This is drained externally and the stone removed at the same time.

SURGICAL TREATMENT OF RANULA

These sublingual cysts are very difficult to eradicate and may tax the patience of everyone concerned (Fig. 8-37). They may be treated by: 1, the use of a seton; 2, marsupialization; or 3, excision. In any method, it may be advisable to insert probes into one or both submaxillary ducts beforehand to prevent injury to them during the operation.

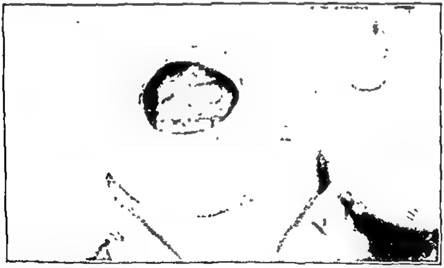


Fig. 8-37. Ranula Differentiated from dermoid cyst by thin wall, bluish color and content of clear, yellow, mucilaginous fluid.

The seton is easiest for the surgeon and patient, and will cure many of them, though it may have to be repeated two or three times. After putting probes in the ducts, a piece of No. 24 (or larger) silver wire on a large cutting needle is passed through the cyst and the ends cut short and twisted into a small loop. It is left in place 6 to 12 weeks, in order to allow epithelium to grow through the wire holes and create permanent drainage openings. Any recurrence may be treated again in the same manner, or by excision.

30 days, and is practically normal in appearance except that rugae are not present. At this stage the soft tissues may be somewhat humped up from side to side just behind the edge of the bone. The actual lengthening might be said to be the difference between what tissue is used in this humping up and the total distance the edge is set back. This distance may be as much as 2 cm , and is the space between the anterior incision to the posterior edge of the bone. Improvement in speech is usually already noted even though the palate is still a little swollen and tender.

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A B

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also be used for defects from cancer pastes, nomas, gummas, or other causes.

Lateral defects in the lower lip are filled by a triangle swung directly down from the adjacent upper lip, preserving the coronary vessels in a vermilion pedicle (Fig. 8-39). The vertical length of the lower lip triangle is measured with a caliper and a flap on the upper lip of the same length is marked out with a pen and 5 per cent methylene blue. The vermilion edge of the upper lip flap should be only about two thirds as wide as the lower lip defect, as the upper lip will be narrowed by the operation and the purpose of the operation is to restore balance between the lips.

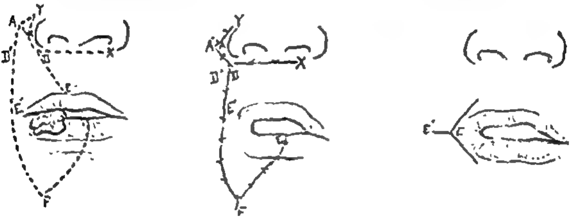

Fig. 8-39. V-excision of carcinoma in lateral portion of lower lip and closure with vermilion-bordered (Abbé) flap from upper lip. See text for details. (From Brown. Surg., Gynec. & Obst., 45:701, 1928.)

The lines EA and E'A are lightly incised with a No. 15 blade, and then cut completely through the lip with a No. 11 blade, being very careful to avoid cutting the vermilion pedicle and coronary vessels at E. These vessels are usually at the level of the skin-vermilion junction and nearer the inside than the outside of the lip, so that it is safe to cut just through the skin down to the vermilion, but the mucosa should not be cut through down so close to the mouth opening.

The flap is then swung around down into place so that the pedicle forms the new angle of the mouth. The mucosal surface is closed first with interrupted catgut sutures and then the skin with fine, interrupted silk sutures. The upper lip defect is closed by pulling the lip over to the cheek, excising a small triangle at A'AY if there is any tendency to a dog-ear at that point. DX shows a relaxation incision that is seldom necessary.

It is sometimes advisable to do a small secondary operation three or four weeks later to further open the new angle of the mouth. This may be done by making the Y opening shown and closing it as a V, or by simply opening the angle of the mouth laterally for a centimeter or so and getting a vermilion covering for the raw edges by swinging small mucosal flaps out from the inside.

Central defects in the lower lip may be closed by the procedure shown in Figure 8-40, closing the original defect by a flap from the lateral side of

In marsupialization, the entire top of the cyst is cut off and the floor of it is sutured to the floor of the mouth all around. This seems like a good plan, but the circular scar created contracts down to a pin-point opening all too frequently.

Surgical excision is difficult because the sac is so thin and friable. It is done under general anesthesia (preferably) with a Magill endotracheal tube) and care is taken to avoid injury to the submaxillary ducts or lingual nerve. Most of the wound can be loosely closed, but a small iodoform drain is placed to the most dependent portion. The floor of the mouth and tongue may swell a good deal afterwards, embarrassing swallowing and even breathing for a few days. However, excision is the treatment of choice when it can be done satisfactorily.

Any nodule or ulcer persisting in the vermilion of the lower lip in an adult is probably carcinoma and should be regarded as such until proven otherwise by biopsy or excision. If the lesion is small, it should be removed completely for examination.

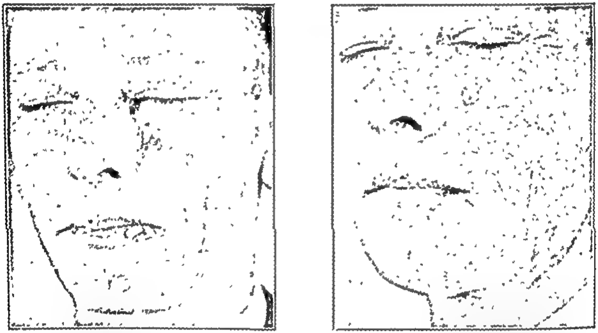

Fig 8-38 Carcinoma of lip treated by wide local oval cautery excision and healed by almost invisible scar Small carcinoma of cheek treated in some manner Important part of treatment was the bilateral upper neck dissection

Oval excision with the cautery, and sewing a small pack in the wound, is often the quickest and easiest method for small lesions and leaves a surprisingly small scar (Fig 8-38) Sharp V-excision can be done closing the wound in layers when small, and filling the defect with a vermilion-bordered (Abbé) flap when larger. The old German operations of advancement of large rectangular flaps are to be avoided whenever possible.

Switching of Vermilion-bordered Lip Flaps. The blood supply through the coronary vessels makes it possible to turn a full thickness flap from one lip to the other on an extremely narrow pedicle. This is principally used for immediate repair of defects from V-excision of lip carcinomas, but may

also be used for defects from cancer pastes, nomas, gummas, or other causes.

Lateral defects in the lower lip are filled by a triangle swung directly down from the adjacent upper lip, preserving the coronary vessels in a vermilion pedicle (Fig. 8-39). The vertical length of the lower lip triangle is measured with a caliper and a flap on the upper lip of the same length is marked out with a pen and 5 per cent methylene blue. The vermilion edge of the upper lip flap should be only about two thirds as wide as the lower lip defect, as the upper lip will be narrowed by the operation and the purpose of the operation is to restore balance between the lips.

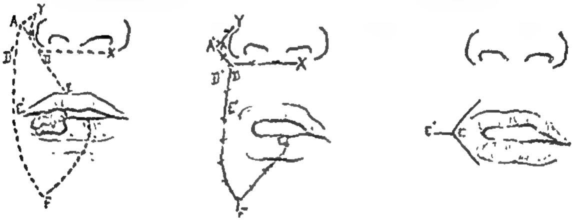

Fig. 8-39. V-excision of carcinoma in lateral portion of lower lip and closure with vermilion-bordered (Abbé) flap from upper lip. See text for details. (From Brown, Surg., Gynec. & Obst., 45:701, 1928.)

The lines EA and E'A are lightly incised with a No. 15 blade, and then cut completely through the lip with a No. 11 blade, being very careful to avoid cutting the vermilion pedicle and coronary vessels at E. These vessels are usually at the level of the skin-vermilion junction and nearer the inside than the outside of the lip, so that it is safe to cut just through the skin down to the vermilion, but the mucosa should not be cut through down so close to the mouth opening.

The flap is then swung around down into place so that the pedicle forms the new angle of the mouth. The mucosal surface is closed first with interrupted catgut sutures and then the skin with fine, interrupted silk sutures. The upper lip defect is closed by pulling the lip over to the cheek, excising a small triangle at A'AY if there is any tendency to a dog-ear at that point. DX shows a relaxation incision that is seldom necessary.

It is sometimes advisable to do a small secondary operation three or four weeks later to further open the new angle of the mouth. This may be done by making the Y opening shown and closing it as a V, or by simply opening the angle of the mouth laterally for a centimeter or so and getting a vermilion covering for the raw edges by swinging small mucosal flaps out from the inside.

Central defects in the lower lip may be closed by the procedure shown in Figure 8-40, closing the original defect by a flap from the lateral side of

the lower lip and then closing that defect with a flap from the upper lip. Both flaps can be switched in the same operation.

Curing Patients with Carcinoma of the Lip. Local lesions can be cured by *radiation in any approved form, by various cancer pastes,* by cautery removal, or by surgical excision. Cautery excision is often the quickest and easiest, as well as the most certain. In any event, the deaths from lip cancer are from the neck metastases, and the management of the cervical lymphatics is the important factor in saving life. Here, as elsewhere, the rule should be to do routine neck dissections (bilateral upper ones, in this instance) with occasional deviations from it when the lesion is low grade, early, and one can follow the patient closely.

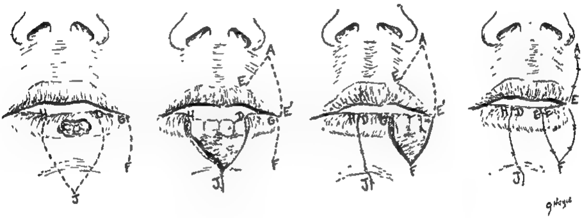

Fig 8-40. V-excision of carcinoma in middle of lower lip and plan for closure, utilizing flap from upper lip See text for details (From Brown. Surg, Gynec. & Obst, 48:701, 1928)

TREATMENT OF CARCINOMA OF THE MOUTH

In an adult, an ulcer in the mouth that persists longer than three weeks, or that is indurated, should be considered as carcinoma until proven otherwise by biopsy. The commonest chronic mouth ulcer in syphilitics is carcinoma, not gumma. Vincent's organisms and yeast-like organisms can often be recovered from the surface of mouth cancers, but should not confuse the diagnosis.

Carcinoma of the mouth is usually best treated locally by radiation, unless it has invaded bone, where it becomes insensitive to radiation. Interstitial implantation of radon seed is often the most accurate method for carcinoma of the tongue (Fig. 8-41), floor of the mouth, buccal mucosa, tonsil, pillars, and soft palate. Seed can be obtained in ½, 1, and 1½ mc. sizes and implanted in a pattern to give fairly uniform radiation throughout the tumor and immediately adjacent tissues, with minimum damage to the face, neck, and other distant structures. The size of the seed used depends upon the probable sensitivity of the tumor (as shown by the gross and microscopic appearance), the thickness of the tumor, and the thickness of the structure being radiated. One millicurie seed are most often used, but they might burn a hole through a lip or soft palate of normal thickness, so that ½ mc. seed are often used in these locations. Very thick tumors in other locations may require 1½ mc. seed to get sufficient d[illegible] or two

layers of 1 mc. seed. The seed are so distributed as to provide the equivalent of 150 to 200 mg. hr. of radium to each cubic centimeter of tissue being radiated, and a margin of apparently normal tissue of at least 1 cm. in every direction should be radiated. In computing dosage, 1 millicurie of radon is equivalent to 133 mg. hr. of radium. In most mouth cancers, the equivalent of 2000 to 4000 mg. hr. of radium is used, depending upon the size and probable sensitivity of the lesion. A lesion that is undertreated once becomes very refractory to radiation and this is important not only in providing a large enough initial total dose, but in getting an initial uniform pattern of radiation throughout the area. Considerable experience is required in order to do this.

A B

Fig 8-41 A, squamous cell carcinoma of tongue in common location on lateral border opposite molar region B, appearance six weeks after radon implantation Area is healed, quite soft and mass has disappeared The atrophy of the papillae in the area and surrounding mucositis are common early sequelae of radiation Note extent of area radiated Neck dissection should also be part of the treatment in nearly all patients with carcinoma of the tongue.

The small celled squamous carcinomas of the nasopharynx, hypopharynx, and tonsil areas are often best treated by external x-radiation, or by some combination of methods. In any event, close cooperation between the radiologist and surgeon is necessary in providing the best treatment for patients with carcinoma of the mouth.

Lesions involving bone, such as alveolar carcinomas or carcinomas of the hard palate, usually require either cautery destruction of the involved bone, or wide surgical excision of it (Fig. 8-42). These are very resistant to radiation, and even if cured, may be followed by a very painful *radioperiostitis* of the adjacent bone.

The complete treatment of any mouth carcinoma always involves two phases: 1, eradication of the local lesion; and 2, the management of the cervical lymph nodes. Here, again, the rule should be to do routine neck dissections, with occasional deviations away from it, rather than to do just occasional neck dissections.

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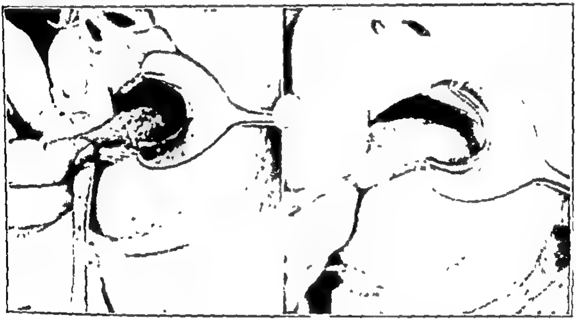

A B

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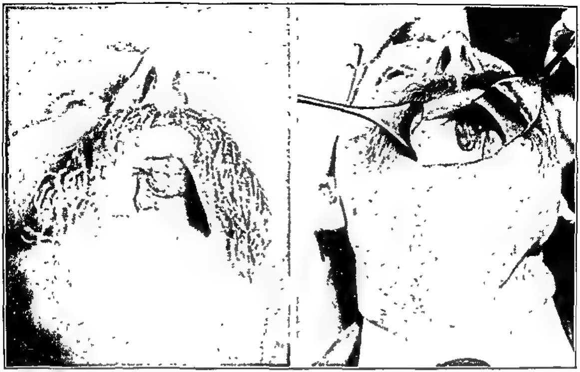


Fig 8-42. A, large squamous cell carcinoma of hard palate B, appearance seven years later following surgical excision of lesion and cautery destruction of edges of defect. Defect left open to permit periodic inspection of the area including the interior of the antrum (these patients can wear dentures with prolongations which fit up into the defect). Note that neck dissection was also done.

TREATMENT OF OSTEOMYELITIS OF THE JAWS

Osteomyelitis of either jaw may be a part of a systemic disease involving multiple bones, but much more commonly originates by spread of a dental infection, particularly an alveolar abscess or pericoronitis.

An alveolar abscess is a pyogenic infection burrowing outward from a tooth root and as such, it is already a localized osteomyelitis. Its onset is characterized by severe, throbbing pain in the area, fever, and swelling of the surrounding soft tissues. Extraction of the tooth in this acute stage is apt to spread the osteomyelitis. The patient should be treated conservatively by chemotherapy, local heat, and analgesics until the abscess first presents on the outside of the gum. The abscess should be opened and a small gauze drain inserted just as soon as it appears, to prevent it from stripping up the surrounding periosteum. After the infection is quiescent, any extractions or necessary dental work may be done to prevent a recurrence of the trouble.

Pericoronitis is a cellulitis of a gum flap over a partially erupted tooth, usually a lower third molar. Extraction of the tooth opens up the underlying bone to the infection and may result in a serious osteomyelitis, if done in the acute stages. This cellulitis should be treated here as elsewhere, by chemotherapy, local heat, and resting the part (limiting chewing and talking). The gum flap may be excised, or the tooth extracted, after the infection has subsided.

Osteomyelitis is much more common in the mandible than in the maxilla, and the majority of cases follow local instrumentation in the presence

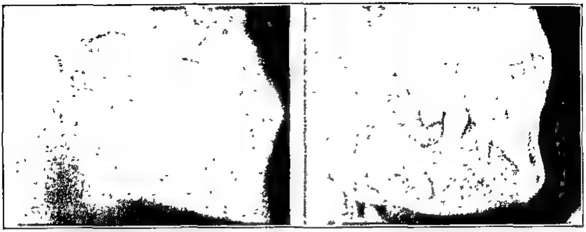
of one of the above acute infections. The onset is accompanied by chills, high fever, prostration, and severe throbbing pain in the area. Trismus rapidly develops from spasm of the closing muscles. Initial treatment consists of chemotherapy, local heat, resting the part, and general supportive measures such as oxygen, parenteral fluids, and blood transfusions when necessary. Pain may be relieved somewhat by codeine, but morphine or other respiratory depressants should be avoided if the swelling is encroaching on the airways. A local soft tissue abscess will usually be ready for drainage on about the fourth day. The decision in regard to this is reached in reference to localization of the swelling as the area may remain hard and not become fluctuant. Drainage should always be dependent, through the upper neck (see section on drainage of jaw abscesses).

During the initial weeks, the sole surgery should *consist* of *adequate* drainage of all soft tissue abscesses. X-ray films are made at intervals, and when definite sequestrae have loosened, with enough surrounding involucrum to support the jaw, they are removed. Chisels, rongeurs, or other bone-cutting instruments should not be used on these jaws. Loose teeth are left in place, unless they are ready to fall out, as it is surprising how many of them will tighten up later and function well.

REMOVAL OF CYSTS AND TUMORS OF THE JAWS

A smooth, rounded, radiolucent area in the jaw may be either a cyst or tumor and at times it is impossible to make a positive preoperative diagnosis. Multilocular areas in the posterior part of the body or in the ramus of the mandible are usually adamantinomas, but may be giant cell tumors. Cystic areas surrounding retained tooth root fragments are usually simple epithelial cysts, requiring only removal of the bony roof for exposure and shelling out with a small, sharp, periosteal elevator. Cysts surrounding a vestigial, unerupted tooth are usually dentigerous cysts, requiring the same treatment. Multiple cysts are apt to be on the basis of hyperparathyroidism and require removal of the parathyroid adenoma, in addition to local removal or curettage of the cysts.

The typical *adamantinoma* near the angle of the jaw can be exposed inside the mouth (Figs. 8-43 and 8-44), by splitting the overlying soft tissues and separating them to either side with an elevator, and removing the bony roof with chisels and rongeurs. If it is an adamantinoma, the tumor will be mostly cystic, filled with a clear, light yellow, thin fluid that contains cholesterin crystals that sparkle in the light It is essential to remove all of these tumors with a small sharp periosteal elevator, preferably in one piece, and thoroughly curet the remaining cavity. If it is thought that any tumor cells may be left, the cavity may be painted with pure phenol, and then alcohol, or may be cauterized with the surgical diathermy. It is then packed open with iodoform gauze soaked in balsam of Peru, and this packing is changed every few days until the cavity has been obliterated by granulations. If the adamantinoma has eroded through bone and extends into the adjacent soft tissues, a block resection of the involved portion of the jaw and surrounding soft tissues should be done instead.



A B

Fig 8-43. A, initial laminagram of adamantinoma of ramus B, appearance of ordinary lateral x-ray year later following removal from the inside of the mouth. Area has healed in with new bone.

Fig 8-44. Postoperative photographs of patient whose x-rays were shown in Figure 8-43 No external scars and continuity of jaw and occlusion maintained. Mouth opening normal.

Giant cell tumors are exposed and treated in the same manner as adamantinomas, except that they are more easily cured and they may be associated with hyperparathyroidism in some instances. When first exposed, they are composed of a reddish, gelatinous material that has been described as resembling currant jelly.

One of the common tumors of the mouth is the *epulis* (Fig. 8-45), which is a benign fibrohemangioma which may or may not contain giant cells. It arises from around the neck of a tooth, or retained root fragment, and is pedunculated at that point If composed predominantly of fibrous tissue, it will be hard and white, but if it is mostly angioma, it may be soft and spongy and either red or blue in color. Treatment consists of excision, together with removal of the offending tooth or root fragment, and cautery destruction of the peridental membrane in the socket.

Fig 8-45. Fairly typical epulis of lower jaw. This one contained a good many blood vessels and giant cells. Removal of involved teeth along with the tumor necessary.

Fig. 8-46 Preoperative and postoperative views of a torus palatinus.

Fig. 8-47. Postoperative photographs and x-ray of patient who had an osteogenic sarcoma of the mandible resected three years previously Continuity of jaw maintained by means of internal steel pin bridging the fragments This can be replaced later with a bone graft if necessary. (From Byars and McDowell. Surg, Gynec & Obst, 84.870, 1947)

Cysts of the hard palate are unilateral, occurring just behind the incisor teeth and extending from the midline, laterally over to the gum. Because they occur in the region of the incisive foramen, they are often called incisive canal cysts, but they sometimes expand upward into the floor of the nose and are then known as nasopalatine cysts. Most of them are best removed through the mouth under general (endotracheal) anesthesia.

An incision is made just inside the teeth all the way around, and the mucoperiosteal layer of the hard palate is reflected backward as a flap, separating it with a small, sharp, periosteal elevator. The thin bone overlying the cyst is removed with a small rongeur and the cyst is then enucleated with small palate and nasal elevators, preferably in one piece and without piercing the floor of the nasal airway. The palate flap is then sutured back down in place, with a small gauze wick drain brought out between the stitches. The drain is removed in two or three days and the sutures in two to three weeks. Postoperative care is same as for cleft palate repair.

Torus palatinus is a benign exostosis occurring in the midline of the hard palate in middle aged or elderly people (Fig. 8-46). It usually has a groove in the middle, coinciding with the bony suture line. It is of importance only when it becomes irritated mechanically, or by hot foods, or interferes with wearing a denture. In removing it, all possible mucosa is elevated off the bone in two lateral flaps and saved. The exostosis is then chiseled off, taking care to avoid penetration into the nose, and the mucosal flaps sutured back in place.

Any bone tumor can occur in the jaws and the more unusual ones require approximately the same treatment as elsewhere in the body—simple excision for the benign tumors, and radical excision, radiation, or both for the malignant tumors (Fig. 8-47).

NECK OPERATIONS

General Considerations. Unless otherwise noted in the following descriptions, the operations in this area are preferably performed under general endotracheal anesthesia in adults and older children with a Magill tube brought out of the nostril and its connections over the forehead so as to be out of the way. Pharyngeal insufflation can be used in small children. In either event, it is important to have an anesthetist who knows when the patient is breathing *without effort*, and who knows what to do to secure free and easy exchange with the patient's head in an overextended position. A falling blood pressure before the operation is well started usually means that the tube is in a bronchus rather than the trachea, or that there is partial obstruction of the airway someplace between the coryna and the machine. Local anesthesia, with suitable combinations of deep third division trigeminal block, deep cervical blocks, and subcutaneous infiltration under the incision, can be used when general anesthetics are not desirable, but they are often more difficult for both the surgeon and the patient.

Pressure dressings are used after most neck operations to keep down edema, prevent serum accumulations and subsequent infections, and thus

secure smoother healing. After covering any suture lines or raw areas with fine mesh grease gauze, mechanic's waste is fluffed about the neck and wrapped on with a gauze roll, making one turn around the neck, one around the forehead, and one under the chin and over the top of the head which passes in front of both ears. A final bandage may be wrapped snugly outside of this, but care must be taken to have sufficient padding over the larynx and trachea and to avoid any constricting bands of gauze in this area. The patient is checked before he leaves the operating room to see that his respirations are free and easy, and a suction machine is provided at the bedside to keep the throat clear of secretions. All participating in the postoperative care should be familiar with the signs of partial airway obstruction in this area. These are: 1, undue restlessness; 2, increasing pulse rate; 3, intercostal and suprasternal retraction; and 4, cyanosis is almost a terminal sign.

A small dose of morphine may be used as a preanesthetic drug (¼ grain doses are *not* desirable). No morphine, or other respiratory depressants, should be used in the immediate postoperative period.

Neck surgery presents many hazards because of the intimate relationship of many small, but important, structures in this area. It should be undertaken only by one who is a well trained surgeon and who, in addition, is so familiar with the minute anatomy of the neck that he can recognize all structures presenting through an incision made anyplace in the neck.

Two of the greatest safety factors in neck surgery are: 1, incisions large enough for adequate exposure; and 2, complete hemostasis at all times. This is no place for operating in a small, deep, bloody hole.

EXCISION OF THE SUBMAXILLARY SALIVARY GLAND

Indications. Removal may be required because of tumor or stones. There are lymph nodes within the capsule of the gland so that tumors should be investigated to determine whether they might be primary lymphatic neoplasms, metastases from mouth or lip carcinomas, or primary salivary gland tumors. Of the latter, the most common are the mixed tumors and in the submaxillary gland about three fourths of these are malignant and one fourth benign Malignant mixed tumors require an associated neck dissection. Malignancy can sometimes be determined preoperatively by fixation to the mandible or other contiguous structures, or by the presence of enlarged nodes in the lymphatic chain below and posteriorly. If it is thought that the lesion is a benign mixed tumor, this should be checked by frozen microscopic sections before the operative incision is closed.

Stones are usually visible on occlusal or lateral jaw x-ray films. Removal of the gland is indicated only if the stones are in the gland proper and it is thought that they cannot be extracted through the duct.

The gland can be excised through the neck, or through the floor of the mouth, but the latter may be dangerous because of difficulty in controlling bleeding from the facial artery and vein.

Operation. An incision is made parallel to the body of the mandible, and about two thirds of the way down from the mandible to the hyoid bone

(Fig. 8-48, left). About 3 inches is the proper length for the incision in an adult. It is carried through the skin, fat, and platysma muscle, and these three structures are raised as a flap upward to expose the gland. (The inframandibular branch of the facial nerve runs within the platysma about 1 inch below the mandible, so that it is important to raise all of this muscle in the flap to protect the nerve.) The lower end of the gland usually hangs down superficially over the digastric tendon and can be readily identified at this point. The facial vein is readily visible coming down over the gland and is divided and ligated at the lower border (Fig. 8-48, right). The

Fig 8-48. Left, dotted line shows line of external incision for removal of submaxillary salivary gland Right, the facial vein is ligated and divided and the gland dissected out.

areolar tissue in the fossa posterior to the gland and above the posterior border of the digastric muscle is then dissected by spreading with scissors and the tortuous facial artery is identified here, divided and ligated firmly. The lower pole of the gland is then picked up with a Jacobs or Allis forceps and rotated up out of the neck as the areolar tissue deep to the gland is divided by gauze dissection or spreading with scissors. The twelfth nerve can be identified running horizontally on the surface of the mylohyoid muscle just above the digastric tendon and it is followed anteriorly until it disappears through the hiatus in the mylohyoid. The areolar tissue and fat is cleaned out of this hiatus and it will then be seen to contain three structures. From below upward they are: 1, the twelfth nerve; 2, Wharton's duct surrounded by the sublingual gland; and 3, the lingual nerve (Fig. 8-49, left) The duct is ligated and divided as far anteriorly as possible and the lingual nerve is traced posteriorly along the superior edge of the gland. The chorda tympani branch from the lingual nerve to the gland will be found about midway along this edge and it is divided, allowing complete removal of the gland. The hemostasis is made complete, the fossa irrigated out with saline solution, a small rubber tissue drain placed from the fossa down out the middle of the incision, and the latter closed. Subcuticular interrupted ooo white silk sutures can be used for the main closure, with a number of tiny interrupted oooooo black silk sutures for the skin, and a pressure

dressing is applied. The patient is usually out of bed the next day and the first dressing is done about the fifth day, when the drain and skin sutures are removed.

THYROGLOSSAL DUCT CYSTS

Indications. The presence of such a cyst or sinus is indication for its removal, though this may be postponed in young babies until they are one or two years of age. Numerous attempts have been made to obliterate these with caustics and cauteries, but complete surgical excision clear up to the foramen cecum is the method of choice. Most midline tumors in the hyoid region are thyroglossal cysts, but occasionally one sees midline dermoids (without a stalk), abscesses from lower incisor teeth (often in diabetics), or submental lymph nodes enlarged by metastatic carcinoma or tuberculosis, in this area.

Operation. If the cyst is acutely infected, it is drained, and removed after the infection is relatively quiescent.

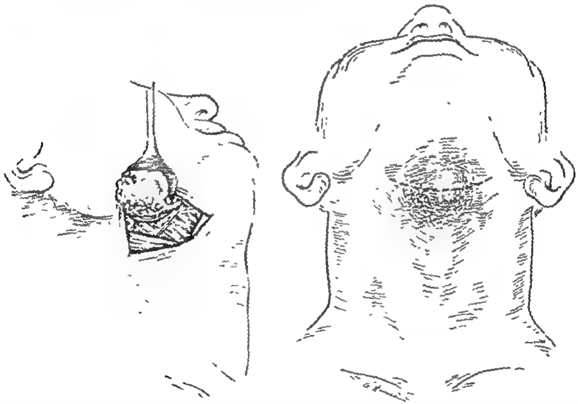


Fig. 8-49 Left, gland dissected out and rotated upward on to the cheek. To remove it, it is necessary to divide the facial artery (in the upper posterior angle of the wound), the duct (between the twelfth and lingual nerves in the mylohyoid hiatus), and the chorda tympani (small nerve branch to the gland from the lingual nerve). Right, dotted line shows external incision for removal of thyroglossal duct cyst.

When there is an opening through the skin, it may be injected with methylene blue, or a probe inserted through it on up into the mouth, or both, for purposes of identification during the excision. If the skin is freely movable over the cyst, a horizontal incision is made over the hyoid about 2 inches in length (Fig. 8-49, right). Otherwise, any area of skin attachment is surrounded by an elliptical incision, extended at either end to the desired

length. If it has not been possible to insert a probe (a *oo* lachrymal probe is a good one) before, the cyst is carefully dissected out, opened, evacuated with a sucker, and a probe inserted through the sinus on up to the mouth. The inside of the sac is also carefully examined for the opening of any sinus track going down toward the thyroid, and a probe inserted in it, if found. A mosquito forceps is clamped on the sac and this forcep and the probe held in the left hand while the dissection is carried out with the right hand. The sinus is dissected down to the center of the hyoid bone (*Fig.* 8-50, left), watching carefully for any solid strand or hollow sinus of thyroid tissue

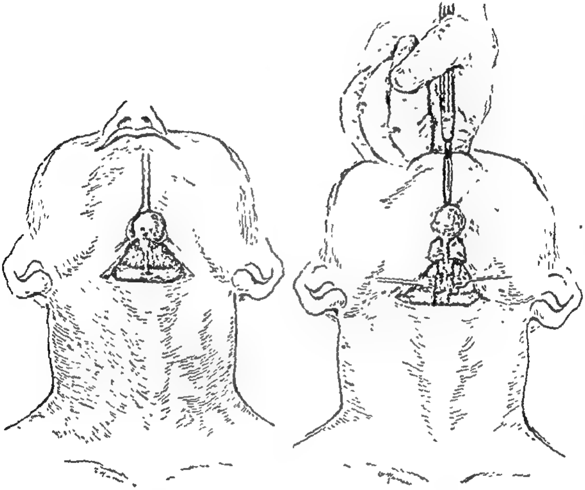


Fig. 8-50. Left, the cyst, and its stalk or duct, is dissected down to the center of the hyoid bone. Right, [illegible] to resect the central b[illegible] n is then carried on u[illegible] foramen cecum at the base of the tongue

extending down to the pyramidal lobe of the thyroid. Any such lower prolongation is removed, of course, and when present there may be other small cysts or aberrant bits of thyroid tissue on either side of it which should be included.

When the hyoid is reached, the periosteum is cleaned from either side of the midline with a sharp elevator and the relationship of the sinus to the hyoid determined. The sinus often passes through the upper portion of the bone in the midline, but may only be adherent to the upper surface, or may

pass through the bone at a lower level. In the first instance, a small V of bone surrounding the sinus may be cut out with a sharp bone cutter, leaving a small bridge below. In the second, the sinus can be elevated out of the central groove with a small sharp periosteal elevator (the Joseph nasal elevator is useful for this). When it passes through the center of the bone, it is necessary to cut completely through the hyoid on either side and remove the central segment with the specimen (Fig. 8-50, right), the periosteum of the two hyoid fragments can be united with a few sutures at the end of the operation.

Above the hyoid, a few mylohyoid fibers can be divided transversely for better exposure, and the geniohyoid muscles are separated with blunt retractors as the sinus is followed up between them. At this point, the surgeon hands over the specimen, mosquito clamp, and probe to an assistant, and inserts his own left index finger into the mouth on back to the foramen cecum. With his right hand, he continues the dissection on up until he can see his gloved left index finger through the oral mucosa. The sinus is removed by cutting a small buttonhole in the mucosa at this point and it is not necessary to suture it. A small rubber tissue drain is placed up to within 1 cm. of the oral mucosa and brought out the middle of the incision. The skin and subcutaneous fat are approximated with fine, interrupted silk sutures and a pressure dressing applied. If the hyoid bone was completely divided, the patient may have trouble swallowing for two or three days postoperatively, and a stomach tube for feeding may be necessary for this period.

LATERAL CERVICAL FISTULAS

These are long epithelial tubes of tiny diameter, vertically placed, with the lower opening in the skin of the neck at the anterior border of the sternomastoid muscle about 1 inch above the clavicle (Fig. 8-51), and the upper opening in the oral mucosa in the general region of the palatine tonsil on the same side. They are present at birth and drain a thin, glairy fluid in small amounts unless they become infected. In each instance, it is important to remove the entire tube clear up to the oral mucosa, or there will be recurrent trouble. For this reason, it is often best to postpone the removal until three or four years of age when the work can be done under endotracheal anesthesia with greater safety and facility.

Operation. A small probe is introduced into the external opening and passed through the fistula up into the mouth. The external opening is surrounded by a tiny, horizontal, elliptical incision which is then prolonged forward and backward in one of the natural creases until it is about 2 inches in length (Fig. 8-52, left). The upper flap is undermined and retracted up to get exposure and the fistula is then dissected out. It will be found to be almost subcutaneous nearly up to the hyoid level, where it goes in deep near the great vessels and up under the posterior belly of the digastric muscle (Fig. 8-52, right). This latter muscle belly is retracted upward and superficially, and the fistula is followed upward behind the submaxillary gland and inside the mandible. Occasionally, it is necessary to make a second horizontal skin incision in the upper neck for adequate exposure at this stage. Care is taken to avoid injury to the carotid, jugular, and fa essels,

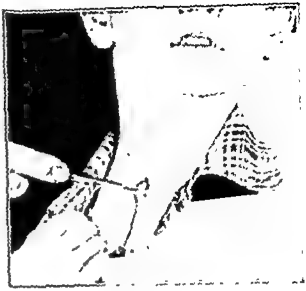


Fig. 8-51. One end of a double-ended probe is inserted into a lateral cervical fistula to show its size, location, and direction.

Fig 8-52. Left the ... button of skin ... sterno-mastoid muscle ... from great vessels.

as well as the important nerves in the area At this time, the surgeon's left index finger is inserted into the mouth and placed against the tip of the probe in the tonsillar fossa (Fig. 8-53). The dissection is carried on upward until the gloved finger can be seen shining through the thin oral mucosa. A disc of this mucosa is then removed with the specimen. The oral mucosa is not sutured, but a small rubber dam drain is placed up to within 1 or 2 cm. of this opening and brought down and out the middle of the skin incision in the neck. The skin incision is closed with fine ooo white silk subcutaneous sutures and ooooooo black silk sutures down to the drain, and a pressure dressing is applied. The drain and skin sutures are removed about the fifth day.

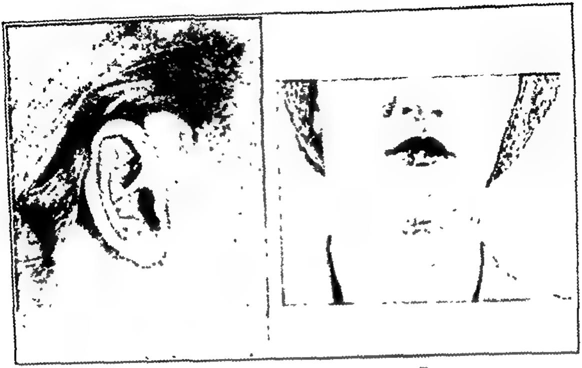
Fig. 8-53. Index finger inserted into mouth and placed against tip of probe as dissection is carried up underneath the digastric muscle and mandible to the oral mucosa. (In practice, a right handed surgeon would prefer to put his *left* index finger into the mouth.)

BRANCHIAL CLEFT CYSTS

There are two clinical varieties, the first branchial cleft cyst, and the lower branchial cleft cyst (Fig. 8-54). The latter term is used to avoid any embryologic discussion here as to its exact mode of origin. If infected, either one should be drained first and excised when quiescent. The first branchial cleft cyst is a soft, subcutaneous mass, usually about 2 to 3 cc. in bulk, situated just in front of the top of the ear and just below the hair of the temple. It is associated with a skin pit or opening in the crus of the helix. Usually, a fine probe can be introduced into this opening and passed forward into the cyst. To remove it, a small elliptical incision is made around the opening and extended horizontally forward over the cyst. The cyst and its external sinus are then carefully dissected out, using the small care in separating it from the parotid as is used in removing any other small, superficial parotid tumor (see excision of parotid tumors). One must especially watch for the branches of the facial nerve to the forehead and upper eyelid. Occasionally, there are deeper sinuses extending downward and forward from the cyst into the substance of the parotid and it may be necessary to open the cyst and pass probes down into these to follow them out.

The lower branchial cleft cysts are often about 20 cc. in bulk and are in the carotid sheath (deep to the sternomastoid muscle) at about the level of the hyoid bone. They are usually fairly hard, spherical, and can be moved easily under the muscle and over underlying structures unless they have been infected previously. They are usually first seen between the ages of 20 and 30 years and are not associated with any masses elsewhere in the neck or mouth. A complete general examination of the patient is in order preoperatively, but even so, it may be impossible in some instances to differentiate them from neurofibromas or enlarged lymph nodes (primary lymphatic tumors or lymph node metastases). For this reason, the surgeon should be prepared to have frozen sections made and to do more extensive surgery if indicated after gross or microscopic examination of the mass.

Operation for Removal of Lower Branchial Cleft Cyst. An incision about 2 inches long is made transversely over the tumor (Fig. 8-55, left), (this incision can be made part of the upper horizontal limb of a complete



A B

Fig 8-54. A, first branchial cleft cyst B, lower branchial cleft cyst.

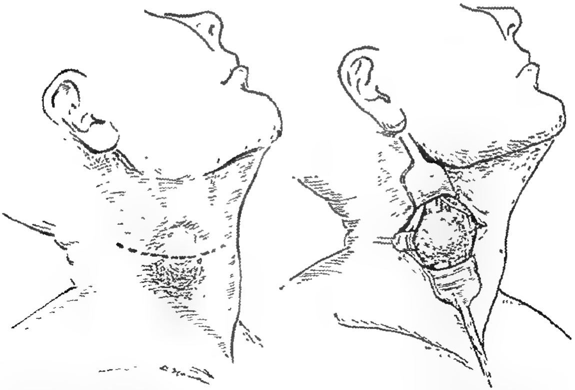


Fig 8-55 Left, skin incision for removal of lower branchial cleft cyst. Right, sternomastoid muscle retracted posteriorly to expose the cyst The cyst is then carefully dissected free from the great vessels and care is taken to avoid injury to the twelfth nerve which is usually just above it, or sometimes subjacent to it The great vessels should be identified both above and below the cyst before its removal

neck dissection incision later if necessary). This is carried down through the fat and platysma muscle to expose the sternomastoid muscle in the posterior half of the wound. The anterior edge of this muscle is lifted up and dissected free from the outer surface of the cyst until the muscle can be retracted posteriorly to expose the entire cyst. The carotid and jugular vessels and the vagus nerve are dissected out and identified below and above the cyst and one watches for possible exposure of the twelfth nerve above (Fig. 8-55, right). Following this, the cyst can often be gently enucleated with the finger, watching carefully for any possible stalk connections with the pharynx (after removal, one can squeeze on the cyst to see if there are any leaks). If the cyst has been infected, it may be necessary to split the sheath around the vessels and carefully remove it by sharp dissection to get the cyst loose. On examination, the cyst has a fairly tough, thick wall, is lined with definite epithelium which is often thrown up into wrinkles and folds, and is filled with a thick white, foul smelling, liquid or paste. Hair or other epithelial structures may be present. The skin incision is closed with deep white and surface black fine silk sutures around a small rubber tissue drain and a pressure dressing applied.

HYGROMAS

Hygromas are cavernous lymphangiomas of the neck and are usually first seen in infancy. They are large, soft, doughy tumors on the side of the neck which may occupy the submaxillary triangle (in which case they also present under the oral mucosa and push the tongue up) or may be in the supraclavicular fossa (*where they may extend down under the clavicle* into the axilla or mediastinum) or in both locations. Some consist of a few large locules; others consist of hundreds of locules, varying in size from that of tapioca to grapes. The locules have walls almost as thin as tissue paper, are lined with a single layer of endothelium, and are filled with a clear, thin, straw colored fluid. When first exposed at operation, they are bluish in color. Occasionally, they may have blood leaks into them.

The excision of a hygroma may become one of the most formidable operations in surgery and should never be lightly undertaken. Removal, or obliteration, can not be postponed indefinitely, however, because of the frequent appearance of secondary infections, or respiratory embarrassment. If the child can be observed closely, it is often wise, though, to postpone operation until six or eight months or even one year of age.

Sudden, large increases in size are usually due to a blood leak into the tumor, or to infection. In such an instance, it may be advisable to insert a large aspirating needle into the mass, and evacuate it, particularly if it is causing breathing or feeding troubles. If the fluid is bloody, about 3 ml. of 5 per cent sodium morrhuate solution can be injected (this will often seal the leak temporarily). If the fluid is pus, the needle opening can be enlarged with a knife, and a drain inserted, as well as starting general chemotherapy, etc.

Operation. The incision varies with the size and location of the tumor, but should be started over the largest mass. If the mass involves the entire neck, it may be necessary to extend the incision until it is exactly like one

for a complete neck dissection, so this should be kept in mind. If it involves only the upper or lower half of the neck, the work can usually be done through a transverse incision.

The opening is carried down to the surface of the cysts and undermining done in all directions in this plane. The cysts are about like sacs of tissue paper full of fluid, so that great care must be taken to avoid rupturing them After exposing a considerable area of the tumor, a decision is made as to the mode of treatment. If it consists of relatively few, but very large locules, it may be best to open one of them and then with the index finger as a dissector, convert them all into one large cavity. This cavity may be packed lightly with a long strip of 2 inch iodoform gauze (about four layers thick)

Fig 8-56 Large hygroma On surgical exposure, it was found to consist of only 3 or 4 large locules These were converted into one cavity and the latter was packed open with 5 per cent sodium morrhuate on gauze Result shown two months later.

wrung out of 5 per cent sodium morrhuate solution (Fig. 8-56). The gauze is brought out of the center of the wound as a drain and is removed the first time on the fifth to seventh day It is replaced with plain iodoform gauze (without sodium morrhuate) which is changed every two or three days after that until the cavity is obliterated. An external pressure dressing throughout this period of packing may help in obliterating the sacs. Recurrences happen occasionally due to the fact that all of the endothelium may not have been destroyed and are dealt with in the same manner, by opening them and repacking It may be better to have to repeat this process two or three times than to carry out the extensive dissection necessary for complete removal.

When the mass consists of hundreds of tiny locules, the above plan is not feasible and one must proceed with complete excision of all of them. An accurate knowledge of the entire anatomy of the neck is essential, as the dissection may extend from the floor of the mouth to below the clavicle, in, around, and between the vessels and nerves in the carotid sheath and brachial plexus regions. A blood transfusion may well be necessary during the operation. The wound is closed and cared for afterward in the same manner as for a complete neck dissection. Any recurrences can be treated by surgical excision, or sodium morrhuate packing, whichever seems best when they are exposed.

It is hoped that the above is not too discouraging a picture, as these cysts can be removed or obliterated in practically all patients by the procedures outlined. Nevertheless, a good deal of work is necessary and the possibility of secondary operations should always be considered beforehand with the parents.

BIOPSY OF CERVICAL LYMPH NODES

The removal of a cervical lymph node for biopsy is not always a simple operation and should only be done by a fairly experienced surgeon in an operating room set up to deal with the contingencies that may be encountered. A careful preliminary examination is necessary, especially of the mouth, nasopharynx, hypopharynx, and larynx, to rule out the possibility of the node containing metastatic carcinoma for which a neck dissection should be done rather than a biopsy.

A horizontal incision is made over the node, being sure that it is of adequate length to expose surrounding structures. The node is dissected out, taking time to maintain complete hemostasis and to recognize and safeguard other important structures. Never work in a small bloody hole in the neck

COMPLETE NECK DISSECTION

Neck dissection is practically the only curative measure for patients with metastatic carcinoma of the cervical lymph nodes and should be employed when the local lesion is controlled or is probably controllable (Figs. 8-57, 8-58 and 8-59). It is not used for tuberculosis of the cervical lymph nodes, as this lesion responds better to radiation. Localized neck lymphomas may be treated by a combination of dissection and radiation.

Complete unilateral dissection from the clavicle to the base of the skull, with removal of the sternomastoid muscle, jugular vein, and carotid fascia, is done when the nodes are limited to one side, as they are apt to be in carcinoma of the tongue, cheek, jaw, tonsil, palate, or floor of the mouth on one side. Bilateral upper dissection is done when metastases are apt to be present in both submaxillary triangles, as in carcinoma of the lip, or anterior floor of the mouth.

For complete unilateral dissection, an incision is made from the mastoid to the opposite point of the chin, passing about 3 cm. below the angle of the jaw. From the middle of this incision, a vertical incision is made downward to a little below the clavicle, approximately transecting the clavicular insertion of the sternomastoid muscle (Fig. 8-60). The skin flaps are raised

Fig 8-57. *Complete unilateral dissection for huge coal-black lymph nodes containing metastatic melanoma (original lesion on temple).* Patient remains well after 13 years (From Brown and McDowell. Ann Surg, 119 543, 1944)

Fig 8-58 Complete neck dissection for huge mass of squamous carcinoma in lymph nodes which surrounded the carotid vessels and necessitated resection of the common, external, and internal carotid arteries Primary lesion has never been found (unless it is primary in the neck), but patient has remained well for seven years. (From Brown and McDowell Ann. Surg, 119 543, 1944)

Fig 8-59 Bilateral complete dissections in patient with carcinoma of tongue. Dissection done on same side when tongue was treated and crossed metastases became apparent about one year later, necessitating dissection of opposite side Well nine years (From Brown and McDowell Ann Surg, 119.543, 1944)

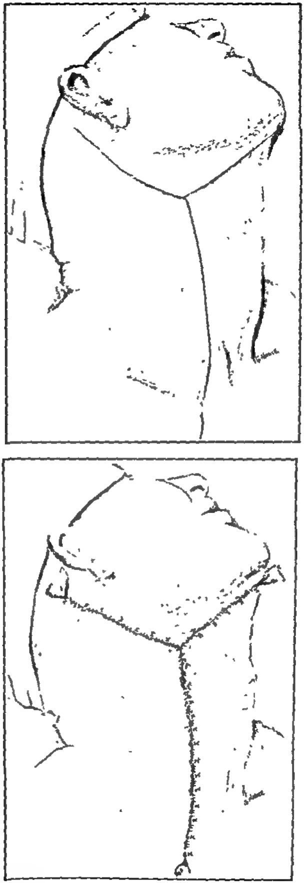
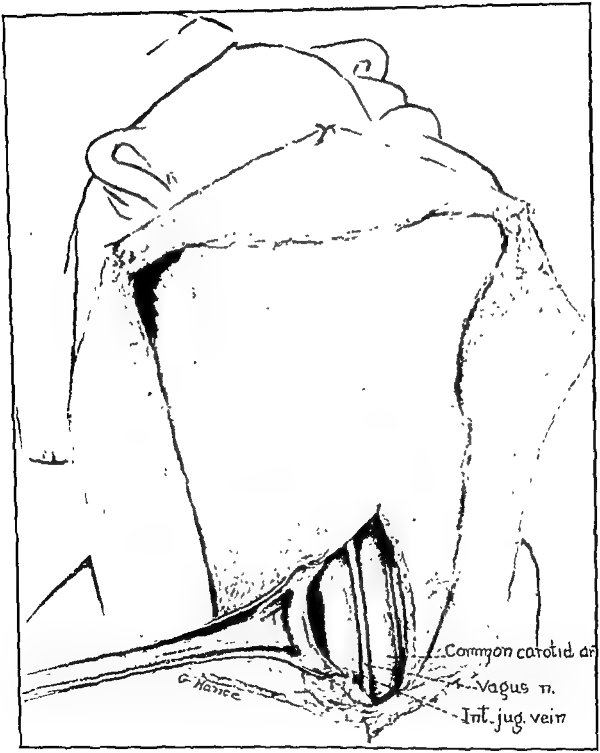
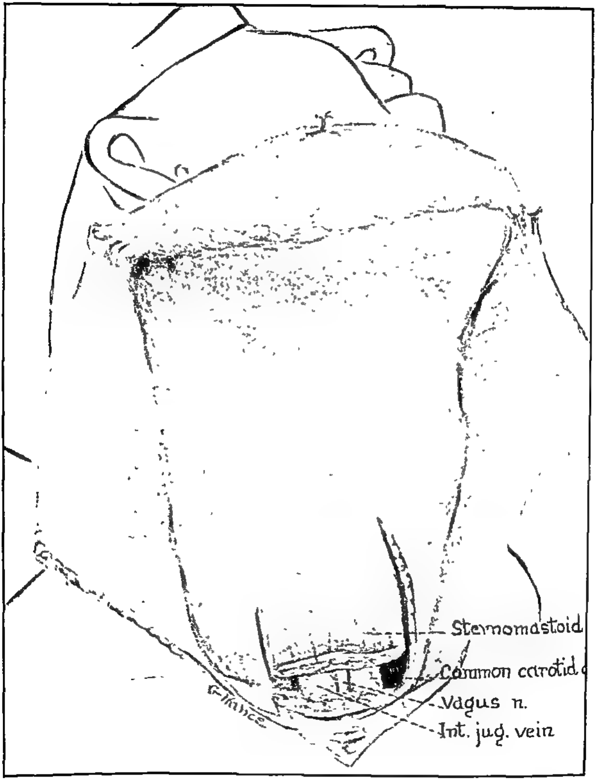


Fig. 8-60. Top, original incisions for complete neck dissection Bottom, method of closing wounds and placing drains at conclusion of operation. (From Brown and McDowell Surg., Gynec. & Obst, 79:115, 1944.)



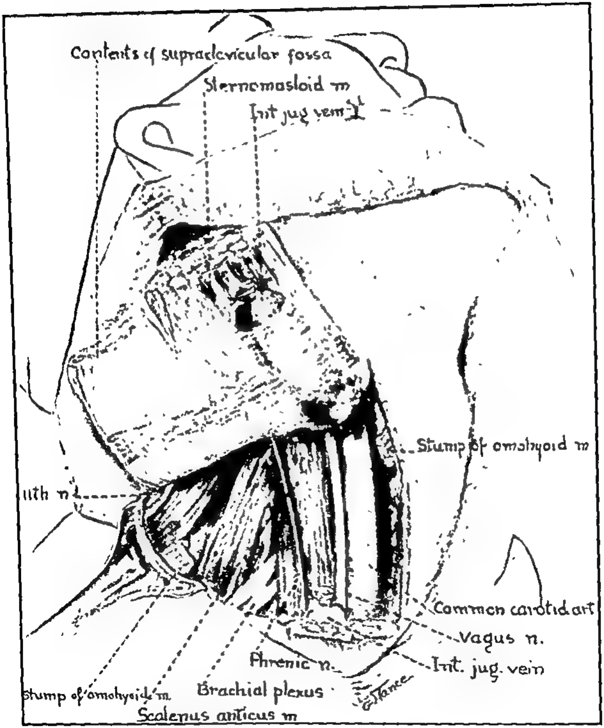
A

Fig. 8-61. A, skin flaps reflected back and great vessels and vagus nerve exposed through vertical incision at anterior border of sternomastoid muscle. (From Brown and McDowell. Surg., Gynec & Obst, 79.115, 1944)



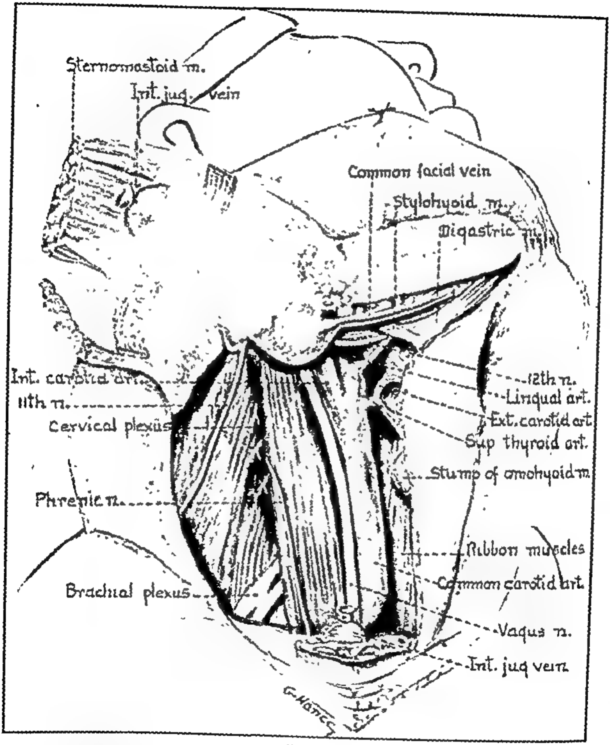
B

Fig. 8-61 (cont.). B, sternomastoid muscle cut loose at lower end (From Brown and McDowell, Surg., Gynec & Obst, 79 115, 1944.)



C

Fig 8-61 (cont.) C, internal jugular vein divided, supraclavicular fossa dissected out, and dissection carried upward on surface of scaleni muscles (From Brown and McDowell, Surg., Gynec. & Obst., 79:115, 1944)



D

Fig 8-61 (cont.) D, showing upward progression of the dissection to level of the hyoid and forward opening over digastric muscle (From Brown and McDowell Surg, Gynec & Obst., 79.115, 1944)

quite thin; the upper one to the upper border of the body of the mandible, the posterior one back to the trapezius muscle, and the anterior one to the ribbon muscles below the hyoid and just past the midline above the hyoid. The flaps are fastened back to expose the entire side of the neck and complete hemostasis is secured.

A vertical opening is then made at the anterior border of the sternomastoid muscle near the clavicle, and the jugular vein, carotid artery, and vagus nerve are separately identified beneath the muscle (Fig. 8-61A). The muscle is then cut loose from the sternum and clavicle and the end retracted upward (Fig. 8-61B). The internal jugular vein is separated, quadruply ligated just above the clavicle, and divided between the middle ligatures. The end of the vein is retracted upward with the muscle, and the fascia surrounding the carotid artery and vagus nerve is divided and stripped upward as the dissection progresses. The supraclavicular fat is divided transversely just above the clavicle down to the scaleni muscles and back to the trapezius.

The dissection is then carried steadily upward on the surface of these muscles and the ribbon muscles, stripping the carotid artery and vagus nerve and avoiding injury to the phrenic nerve, to the level of the hyoid. (Fig. 8-61C and D).

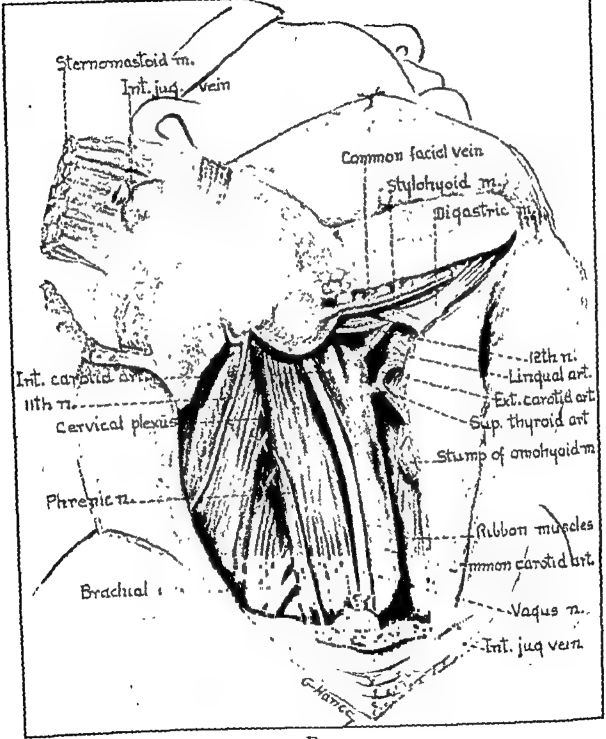
A separate incision is then made horizontally just above the hyoid and just below the submaxillary gland. The tendon of the digastric muscle is identified, with the subjacent twelfth nerve (Fig. 8-61D). The posterior belly and stylohyoid muscle are then divided from the hyoid bone and this incision is extended laterally and down to connect with the previous one at the carotid sheath (Fig. 8-62A).

The subcutaneous fat is cut through down to the underlying muscles posteriorly up to the mastoid and anteriorly up to the opposite point of the chin. The submaxillary gland is rotated upward out of its fossa and freed by dividing the facial artery at its posterior border, the chorda tympani attachment to the lingual nerve at its upper border, and Wharton's duct at its anterior border (Fig. 8-62B and C).

The block dissection is carried on upward at the same level posteriorly as before, and on the surface of the mylohyoid muscle and mandible, anteriorly, until the upper limits of the block are reached at the upper border of the jaw and tip of the mastoid.

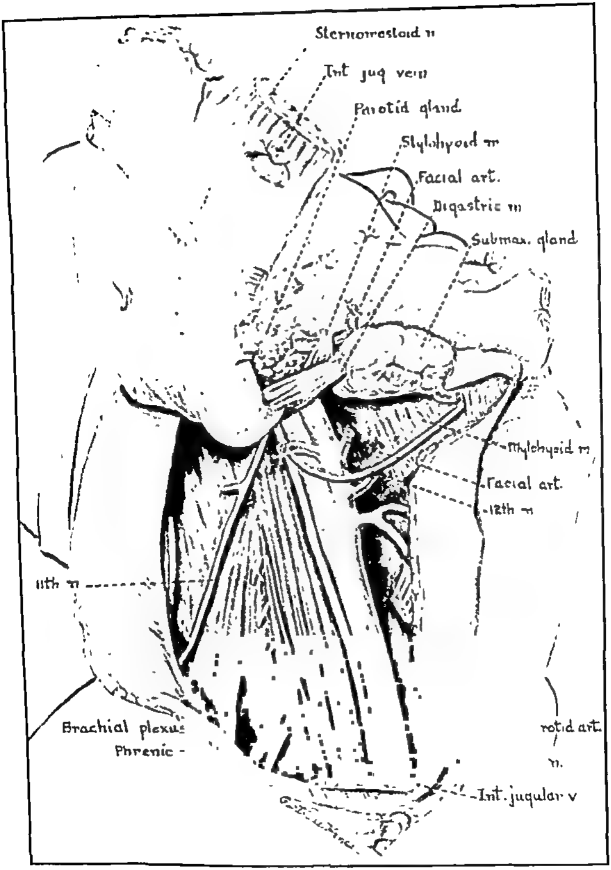
The jugular bulb is identified up near the base of the skull in front of the styloid process, doubly ligated, and divided below the ligatures. The upper end of the sternomastoid muscle and digastric muscle are cut loose from the mastoid, the lower third of the parotid gland is transected, and the remainder of the block is cut loose at the level of the upper border of the body of the mandible, tying the facial artery and vein on the cheek (Fig. 8-62D).

The entire wound is washed out with saline, the skin flaps replaced and carefully closed, bringing 1 inch drains out the anterior, posterior, and inferior incision ends (Fig. 8-60B). A large pressure dressing is applied. The patient's respirations are checked after the endotracheal tube is removed and he is given no morphine or other strong respiratory depressants during the early postoperative course. Patients are usually out of bed on the follow-



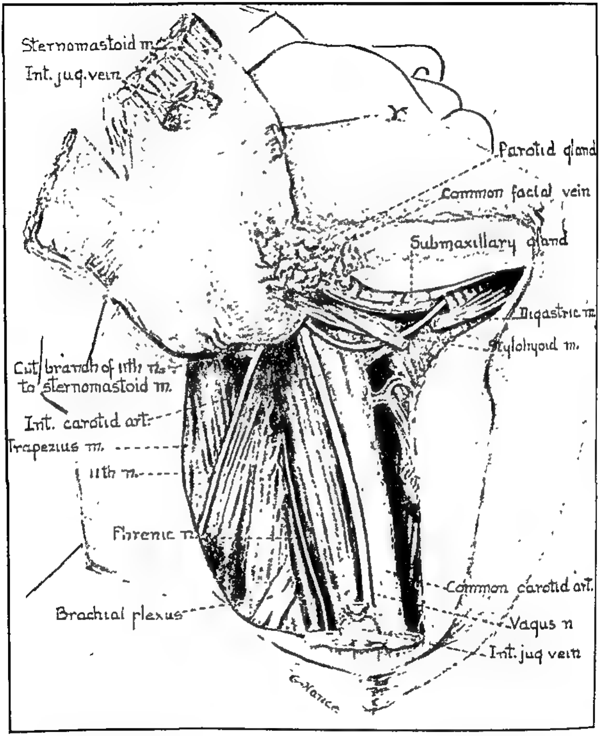
D

Fig 8-61 (cont.) D, showing upward progression of the dissection to level of the hyoid and forward opening over digastric muscle (From Brown and McDowell, Surg., Gynec. & Obst., 79 115, 1944.)



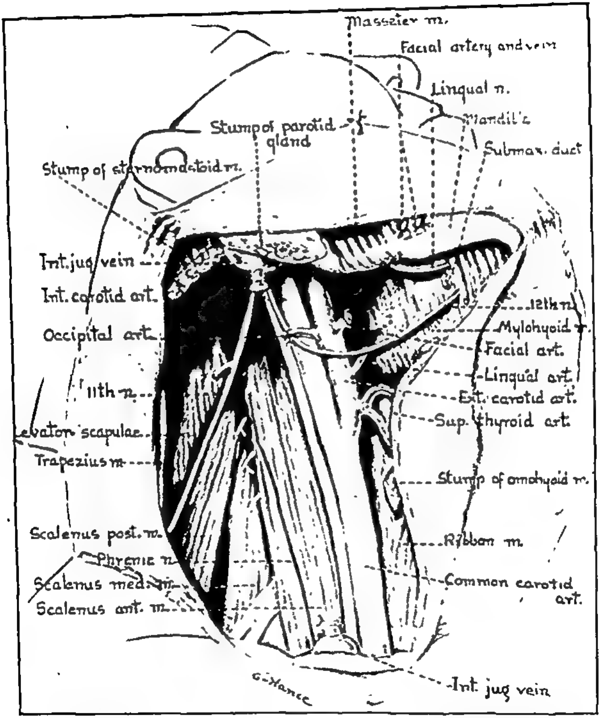
B

Fig 8-62 (cont) B, facial and occipital arteries and facial vein divided and submaxillary gland rotated up out of fossa. (From Brown and McDowell Surg., Gynec & Obst., 79:115, 1944)



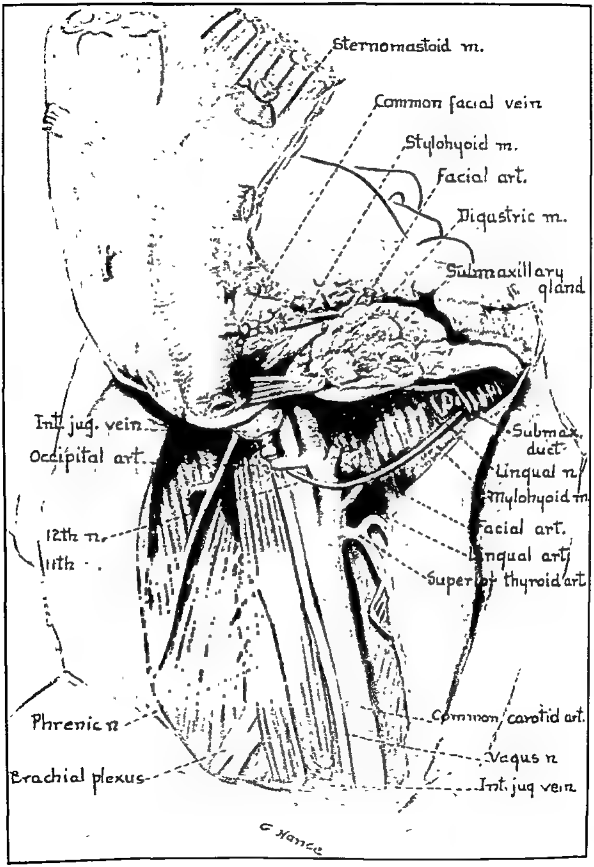
A

Fig. 8-62. A, posterior belly of digastric and stylohyoid muscle cut loose from hyoid bone Eleventh nerve branch to sternomastoid cut. (From Brown and McDowell. Surg, Gynec. & Obst., 79.115, 1944)



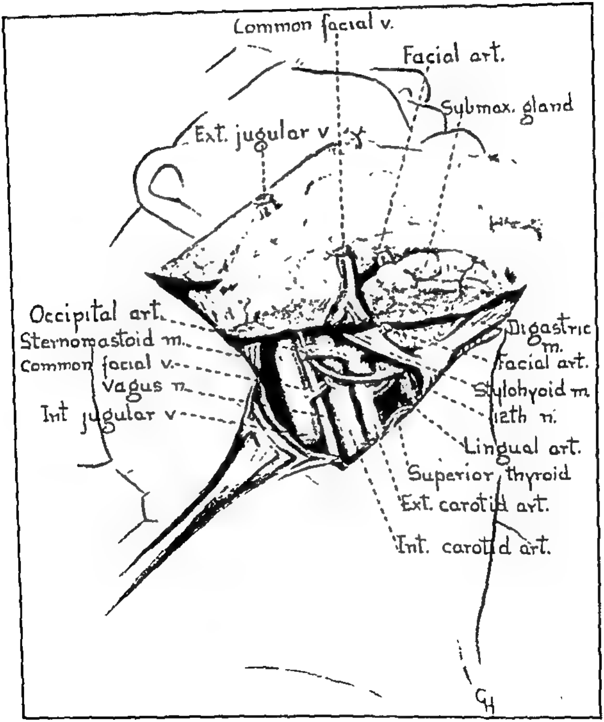
D

Fig 8-62 (cont). D, sternomastoid and digastric muscles cut loose from mastoid, stylohyoid from styloid, lower pole of parotid transected, remaining tissues divided at level of upper border of mandible to remove the entire specimen in one piece. (From Brown and McDowell. Surg, Gynec. & Obst., 79.115, 1944)



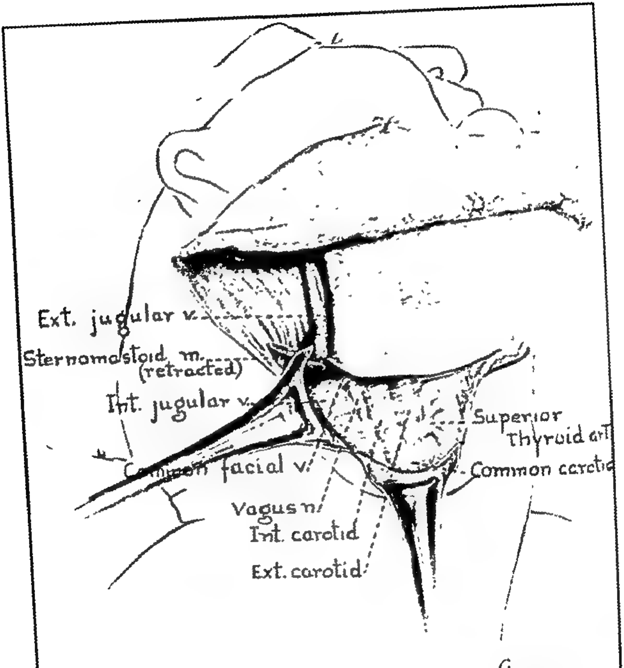
C

Fig. 8-62 (cont.). C, submaxillary duct and chorda tympani cut. Jugular bulb ligated high and divided. (From Brown and McDowell. Surg., Gynec. & Obst., 79:115, 1944.)



B

Fig 8-63 (cont.) B, facial and occipital arteries and common facial vein ligated and divided. Submaxillary gland rotated up out of fossa. (From Brown and McDowell Surg., Gynec & Obst., 79.115, 1944.)



A

Fig. 8-63. Bilateral upper dissection A, Kocher incision and skin flap reflected upward. External jugular vein divided and ligated at lower end of wound Subcutaneous fat and platysma divided all along lower edge of wound Areolar tissue and nodes dissected out of carotid sheath down as low as possible. (From Brown and McDowell Surg, Gynec. & Obst., 79.115, 1944)

ing day, drains removed the seventh day, sutures out and discharged from the hospital on the tenth day. It is important to maintain a good pressure dressing on the flaps, though, for the first 7 to 10 days, changing it as often as necessary to keep it secure.

BILATERAL UPPER NECK DISSECTIONS

An incision is made from one mastoid to the other, crossing the midline just above the hyoid, and the upper skin flap is raised quite thin up to the upper border of the body of the mandible and fastened up to expose the entire upper neck.

One side is dissected at a time as far forward as the midline when the entire bilateral block may be removed in one piece.

The external jugular vein is divided at the edge of the lower skin flap, and the subcutaneous fat cut down to the muscle up to the mastoid and forward over the hyoid to the midline. The fat and lymph nodes in the upper carotid sheath are dissected out and reflected upward with the specimen, but the internal jugular vein is not divided (Fig. 8-63A). The dissection is carried upward on the surface of the sternomastoid muscle, posterior belly of the digastric muscle, internal jugular vein, and mylohyoid muscle. The submaxillary gland is rotated up with the specimen and freed by dividing the facial artery at its posterior border (Fig. 8-63B), the chorda tympani at its upper border, and Wharton's duct at its anterior border.

The lower third of the parotid is cut loose from the remainder of the gland and the mass is taken loose from the mandible to the midline, tying the facial artery and vein on the cheek (Fig. 8-63C).

The wound is washed out with saline, the upper skin flap replaced and sutured. A small drainage hole is left in the midline and one at either end of the incision. A short rubber dam drain is placed in each end to the stump of the parotid, and drains are placed in the midline opening to either submaxillary fossa. A large pressure dressing is applied, taking particular care to get upward and inward pressure on the skin flaps to eliminate any dead spaces in the submaxillary fossae. Postoperative care is the same as for complete neck dissection (Fig. 8-64).

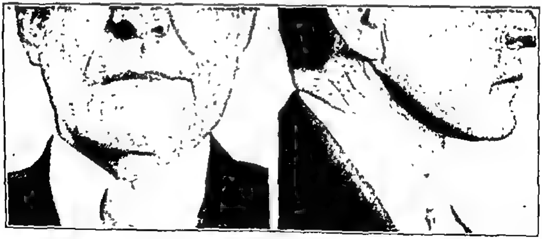
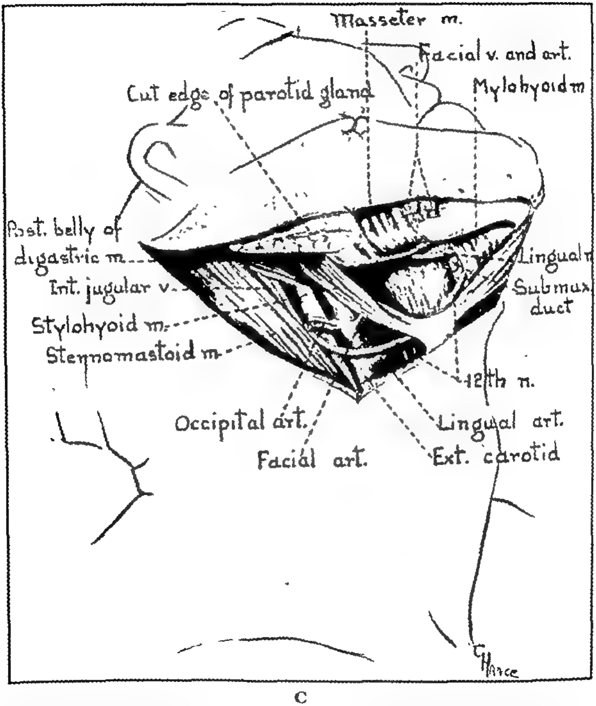


Fig. 8-64. Result of bilateral upper neck dissection for metastatic carcinoma from lower lip Well 14 years. (From Brown and McDowell. Ann. Surg., 119:543, 1944.)



C

Fig 8-63 (cont.) C, submaxillary duct and chorda tympani divided Lower third of parotid transected and remainder of block removed at level of upper border of mandible. Same procedure then carried out on opposite side (From Brown and McDowell Surg, Gynec. & Obst., 79:115, 1944.)

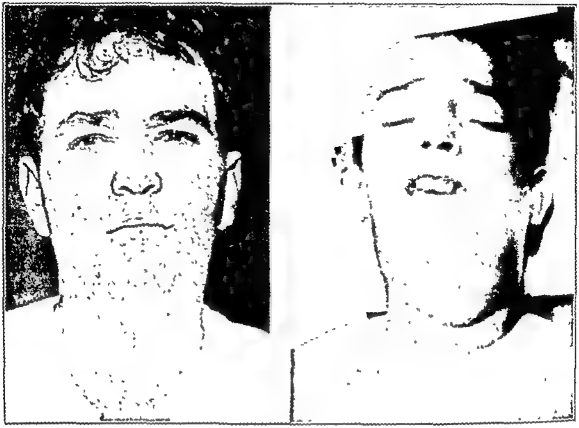
dible. This line may be infiltrated with novocain, and very light pentothal anesthesia instituted. The original knife cut extends just into subcutaneous fat, and a curved hemostat is introduced and the dissection continued upward by pushing it in and forcibly spreading it until the angle of the mandible is contacted. The dissection is then continued upward first on the outer surface of the ramus, then on the inner surface of the ramus, until an abscess is encountered and drained in one or both places. When the abscess is found, an index finger is inserted into it for exploration and to insure that the drainage is adequate. A 1-inch iodoform pack is introduced and the anesthetic immediately discontinued, keeping the throat clear at all times with the suction apparatus.

Chemotherapy is continued during the postoperative period, with parenteral fluids or tube feedings as indicated. The amount of relaxation of the spasm of the closing muscles is a good indication of progress.

The patient may have a localized or generalized osteomyelitis in conjunction with the soft tissue abscess, but any sequestra are not removed until they are entirely loose. Teeth are never extracted until the whole process is quiescent.

DRAINAGE OF NECK ABSCESSES OF DENTAL ORIGIN

These usually originate from infection of the lower molars and may occur spontaneously, or following extractions (Fig. 8-65). The third molar is an especially common source.



A B

Fig 8-65 Neck infections of dental origin A, submental abscess originating from incisors. B, a patient who is critically ill with masseter and internal pterygoid abscesses from a third molar Difficulty in breathing and swallowing made emergency drainage imperative

Many workers have done very meticulous dissections of the fascial planes of the neck, sometimes giving them different names which confuse the surgeon trying to find an abscess in this area. The important thing to remember is that the pus may spill over from the tooth laterally, between the ramus of the mandible and masseter muscle, or medially, between the ramus and internal pterygoid muscle and extending upward along the latter into the soft palate area.

These abscesses usually take about three to four days from the onset to ripen and the patient should be given chemotherapy, supportive treatment, and some relief of pain during this interval Respiratory obstruction is one of the great dangers so that morphine or other strong respiratory depressants should not be used, and the abscess should be opened earlier than usual if the signs of early obstruction appear.

At operation, it is imperative to have a good strong suction apparatus on hand, with a catheter that will go through the nose and clear out the throat if necessary. The skin incision is about 1 inch in length, parallel to the body of the mandible, and about 1 inch below the angle of the man-

prior to elective surgery. Otherwise, breakdown of the wound may be expected to follow an otherwise good reconstructive operation.

Anesthesia. Because many operations in plastic surgery are of long duration, local infiltration anesthesia is ideal in the majority of cases. Naturally though, it is not suited for the average child or nervous adult. We prefer 1 per cent procaine for local infiltration. Unless the patient is hypertensive, or unless the total quantity is too great for the individual case, we add 5 drops of 1:1,000 adrenalin to each ounce of 1 per cent procaine. For rhinoplasties, we use 10 drops of 1:1,000 adrenalin per ounce of 1 per cent procaine. The use of sufficient adrenalin gives a drier operative field and prolongs the period of anesthesia very markedly.

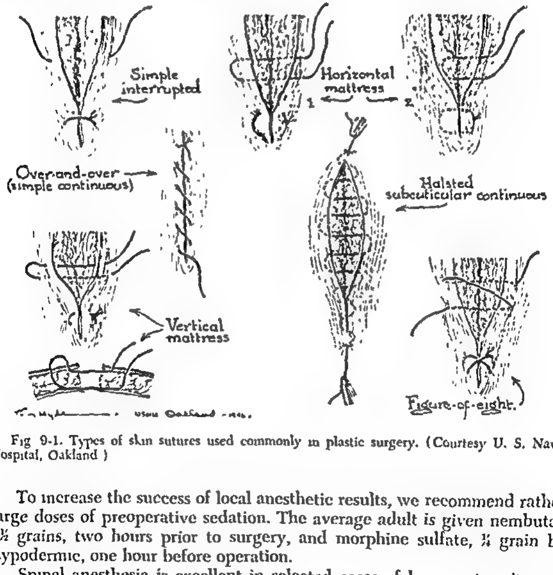


Fig 9-1. Types of skin sutures used commonly in plastic surgery. (Courtesy U. S. Naval Hospital, Oakland)

To increase the success of local anesthetic results, we recommend rather large doses of preoperative sedation. The average adult is given nembutal, 4½ grains, two hours prior to surgery, and morphine sulfate, ¼ grain by hypodermic, one hour before operation.

Spinal anesthesia is excellent in selected cases of lower extremity surgery. Brachial plexus blocks are often indicated.

Of the general anesthetics, ether and cyclopropane are used most frequently. In operations about the head and neck, one should use the endotracheal method so as to eliminate the anesthesia apparatus from the field of operation and to avoid accidental aspiration of blood. Needless to say, this should be given by an experienced anesthetist trained in this special type of work.

9

PLASTIC SURGERY

Paul W. Greeley

The scope of modern plastic surgery has come to cover a very broad field. Primarily however, one deals in the repair and replacement of surface defects all over the body, and in the management of injuries, fractures, and congenital deformities of the face.

Instruments used in plastic surgery are essentially the same as those of the general surgeons. A few special instruments are added for the treatment of certain problems not arising among the routine operations of the other specialities. It is necessary to use many small instruments so as to minimize trauma in the handling of tissues. The instruments must be kept sharp to insure accurate optimum function in their use. All tissues must be handled gently if the best primary union is to be anticipated. Consequently, the judicious use of fine sharp instruments aids greatly in establishing this end.

Suture material, needles, and stitches must be small and nonirritating. For the closure of skin edges, either ooooo monofilament nylon or oooooo black braided silk has been found most ideal. However, other fine nonabsorbable material may be used for surface closures. Most important though, is that all edges must be approximated accurately and without tension. Any stitch that is placed under tension will not give an acceptable final result. All subcutaneous bleeding points must be ligated to secure absolute hemostasis and all dead spaces must be obliterated. For this purpose, one may use either ooooo plain catgut or No. 120 white cotton. Subcutaneous relaxation stitches of oooo chromic catgut often are placed to maintain accurate approximation of the edges until organization is complete.

The needles should be the small, sharp, curved cutting variety. Eyeless needles into which the suture material may be swedged, cause the minimum degree of trauma when inserted.

The different types of stitches used most commonly (Fig. 9-1) are probably not as important as is their accurate insertion without tension. Many small interrupted sutures will produce the most accurate approximation of skin edges The sutures should be removed early, i.e., in two to four days, so as to avoid postoperative stitch-hole scarring. The suture line must be kept clean and free of blood crusts. Otherwise, contamination, infection, and wide scars may ensue.

General Care of the Patient. The fundamentals governing the care of the plastic surgery patient are identically the same as those of any other surgical problem. The debilitated patient, commonly encountered in the management of extensive burn defects, must be prepared with blood and plasma transfusions, along with a high caloric, vitamin, and protein diet. The ingestion of beer and milk often aids this type of patient. Hemorrhage must be controlled and shock treated. Skin infections must be eliminated

the wound is rinsed thoroughly with sterile physiologic saline solution. Failure to remove all loose bits of sand may lead to the development of sand granulomas. The wound is then covered with sterile dressings similar to those used in covering a donor site following removal of a split-thickness skin graft. The dressings are removed in approximately seven days, following which healing is usually complete.

Fig 9-2. Extensive lacerations of the face and compound fracture of the mandible following wound by airplane propeller. Right, healing after careful cleansing of wound, preservation of all tissue, and accurate approximation. (Courtesy of Dr Michael Gurdin and U S Naval Hospital, Oakland)

Fig 9-3 Permanent accidental tattoo following powder burns This could have been avoided by early removal of all foreign material by thorough cleansing with soap and water under adequate anesthesia (Courtesy U. S. Naval Hospital, Oakland)

Avulsions and cutaneous defects following surgical excision should be closed primarily if the wound is not grossly contaminated. Small areas may be closed by primary suture after undermining the border skin flaps. Larger areas should be covered with a properly selected type of skin graft (Fig. 9-5). Avulsed segments of skin, if not contused or otherwise damaged, make ideal replacement tissue providing the tissue is cleaned, its subcu-

The use of sodium pentothal intravenously has very little practical application in the field of plastic surgery except as basal anesthesia. It must be supplemented with an inhalation anesthetic agent or used in conjunction with local anesthesia. The maintenance of an adequate airway is extremely important in either case. Hypotensive anesthesia is often very useful in the maintenance of a dry operative field.

TREATMENT OF FRESH WOUNDS

All fresh wounds should be treated promptly. The additional blood supply of face tissues however, permits greater latitude than with wounds elsewhere on the body. Generally speaking, facial wounds should not be closed after 20 hours, and hand wounds after 6 hours. Exceptions may be made if adequate antibiotic therapy is supplemented, in which case, considerable lapse of time may be allowed if the wound is not grossly contaminated, contused, or necrotic.

In the local repair, gentleness and conservatism are paramount. Open wounds should be washed gently with mild white soap and water—no chemical antiseptics! Next, the area should be irrigated with copious quantities of warm sterile physiologic saline solution. Any grossly devitalized or ragged skin edges should be débrided and all segments of exposed bone left in place. All conserved structures may be of inestimable value if a late secondary repair becomes necessary. Hemostasis must be controlled. The skin edges must then be approximated accurately by suture (Fig. 9-1) and a pressure dressing applied. Drains are not used unless there is danger of hematoma formation and in such a case, the drain should be removed within 24 hours. The skin sutures should be removed within two to four days, following which the suture line should be supported for about three weeks, to prevent widening of the soft early scar (Fig. 9-2).

Accidental tattooing from inground foreign bodies, powder burns, and the like, must be removed at the initial cleansing of the wound. Otherwise, permanent discoloration results (Fig. 9-3) and can only be corrected by complete excision of the tattooed area, or by rubbing gently with sterile sandpaper if the pigmentation is superficial. The initial removal may be accomplished by thorough washing with soap and water and, if necessary, by the use of ether or a similar solvent to remove grease and paint. These procedures are accomplished only under adequate anesthesia.

Abrasive Surgery. Certain superficial types of benign cutaneous pathology can sometimes be eliminated or improved by removing the involved lesions with sterile sandpaper under local or general anesthesia in the operating room. Common varieties are accidental tattoos that follow inground dirt and other foreign material into the skin. Extensive freckles may be amenable. Extensive postacne scarring can frequently be helped. The procedure, however, is limited by the depth of the pathology since sandpapering too deeply will naturally remove so much skin that the balance left will not be cosmetically acceptable.

The operation is ordinarily accomplished by using pieces of oo sterile sandpaper or garnet paper secured around a 1½ by 4 inch round block of wood (Fig. 9-4). After sanding as deeply as seems indicated or justified,

taneous fat excised, following which it is sutured into place and treated thereafter as one would do with any other free skin graft.

SKIN GRAFTS

Skin grafts can be made to grow successfully on practically any viable area that is free of major infection. Fresh surgical wounds make the most ideal base. Skin grafts will also grow on periosteum, bone, perichondrium, tendon, fascia, fat, muscle, or healthy granulation tissue. Granulations however, must be looked upon as infected fields, even though mild, and the simpler types of grafts used over them.

The type of skin graft utilized to cover a given cutaneous defect must be carefully and propertly selected. In general, the thinner the graft, the greater will be its chance of growing. Conversely, the thicker the graft, the more difficult it will be to obtain complete growth, but the maximum degree of function and cosmesis will be obtained. The decision as to what type of skin graft to use is not always an easy one to make, but the degree of uncertainty lessens as the surgeon's experience with various technics increases. The inexperienced operator is apt to choose complicated methods when a simpler procedure would be more desirable, the latter method often yielding better final results and simultaneously being time and discomfort saving to both the patient and the surgeon.

The following simple classification of skin grafts is offered (Fig. 9-6):

- Free grafts
  - Split thickness
    - Thiersch
    - Reverdin
    - Intermediate
    - Stent
  - Free full-thickness (Wolfe-Krause)
- Pedicle grafts
  - Open (direct)
  - Tubed

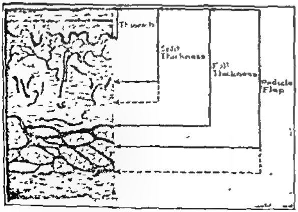


Fig 9-6 Cross section of skin showing relative thickness of various types of skin grafts. (From Greeley U. S. Nav. M. Bull, 42.659, 1944)

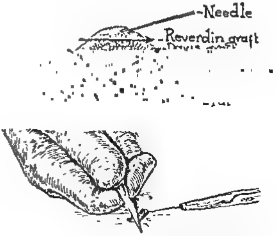


Fig. 9-7. Thick pinch (Davis) grafts theoretically give better surface covering than the thinner (Reverdin) grafts (Courtesy U. S. Naval Hospital, Oakland.)

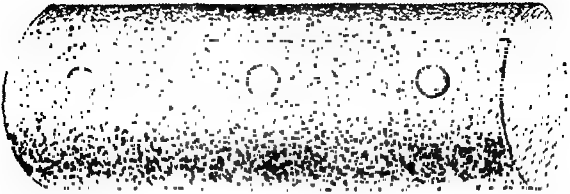


Fig. 9-4 Method of securing sterile sandpaper to wooden block with thumb tacks.

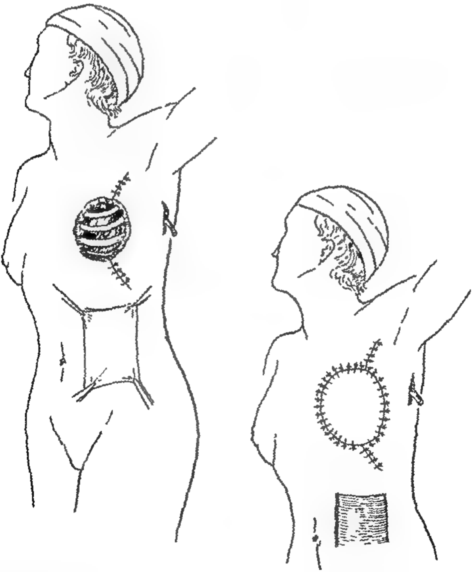


Fig. 9-5. Fresh surgical wounds that cannot be closed by suture should be covered with a split-skin graft at the time of operation

of the defect. These molds are made with softened dental modeling compound, or Stent; hence the grafts are called Stent grafts. After applying a split-thickness graft over the prepared mold (Fig. 9-37), with the raw surface of the graft outward, the mold is reinserted into the cavity and pressure applied as with any other graft.

Full-thickness or Wolfe-Krause grafts will give the maximum degree of cosmetic and functional result, but are the most difficult in which to obtain growth. They are preferred when a free graft for the reconstruction about the face is desired, or in dealing with flexor defects of the hands and fingers. They will grow best on a clean operative wound and should be applied to an area in which there is a good subcutaneous fat pad. They must be cut free of all underlying fat to a pattern of the exact size and shape of the defect (Fig. 9-8), and are secured in place with many small interrupted sutures. Hemostasis of the recipient area must be perfect. Pressure should be applied for 14 to 21 days, although the graft may be inspected earlier for the removal of sutures if the pressure dressing is replaced promptly.

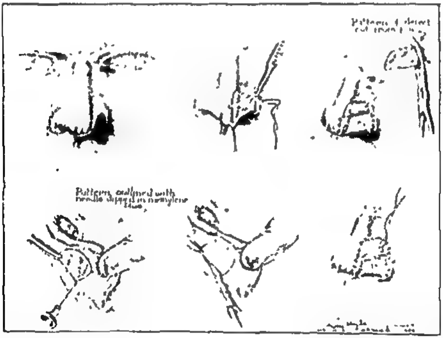


Fig. 9-8 One method of reconstructing ala nasi. Alar rim obtained from rolling skin flap down from above. Cutaneous defect covered with free full-thickness (*Wolfe-Krause*) graft taken from behind ear. All Wolfe-Krause grafts must be cut to an accurate pattern of the defect. (Courtesy U. [redacted] Naval Hospital, Oakland.)

There is no apparent limit as to the size of a full-thickness graft, but the donor area may create a serious problem in closure. Small donor areas may be closed by undermining and suture, but large areas may have to be covered by some type of split-thickness graft. Consequently, there should be positive indications for its use when a free full-thickness graft is selected.

Pedicle flaps may be open or tubed. They are utilized in extensive reconstructions about the face, particularly about the mouth and tip of the nose where both covering and lining are needed, and when there is not a healthy base against which adequate pressure can be made. They are also indicated when it is doubtful whether the viability of the graft can be

Free grafts should always be given first choice, and may be used when there is a healthy base against which pressure can be applied.

The Thiersch graft is a very thin epidermal split-thickness type that is extremely useful for the rapid covering of any surface defect. It is certain to take if simple rules are observed. It grows well even in the presence of considerable infection and can often be utilized to convert an infected granulating defect into a closed wound. It will grow well on any fresh wound, periosteum, bone, perichondrium, muscle, fascia, tendon, or as a substitute for mucous membrane in the mouth or conjunctiva. It will not however, control the underlying fibrosis which invariably develops post-operatively. But it will grow where a graft of greater thickness might not survive. As a temporary measure therefore, whether for a burn or other cutaneous defect, it can often be utilized to great advantage in facilitating rapid healing. Moreover, this covering may be excised later when the operative wound is clean and a thicker graft can be applied successfully.

Reverdin (pinch or Davis) grafts (Fig. 9-7) may have a place in the hands of the occasional operator or to serve as a temporary covering. Their use may be considered in extensive burns when donor sites are at a premium. However, it has been the experience of most plastic surgeons that the percentage of takes is much greater when large sections of skin (as Thiersch grafts) are used.

The final functional and cosmetic result with the Reverdin graft leaves much to be desired in both the recipient and donor areas. The scarring between the islands of skin frequently breaks down due to poor vascularity. Consequently, Thiersch grafts appear preferable to the Reverdin or Davis type.

Intermediate split-thickness grafts have the greatest field of usefulness of all the various types. These might be called thick Thiersch grafts. They can be cut from 25 to 85 per cent of the total skin thickness. The thicker ones have many advantages of the free full-thickness grafts, but are simpler to handle. They may be cut to almost unlimited surface dimension. It is not necessary that they be cut to exact size, since any excess may be permitted to overlap and later be trimmed off at the time of the first dressing. Furthermore, the donor site heals spontaneously. Consequently, thick split-thickness grafts may be used for all practical purposes in many areas where formerly the more complicated free full-thickness grafts was employed. There is ample proof that these grafts will function well on practically all defects of the extremities except the flexor surfaces of the hands. But in selected cases, they may even be used on the flexor surface of the hand, providing a good subcutaneous fat pad is present on the recipient site. Even neck and axillary contractures do well when replaced with large, thick, split-thickness skin grafts.

Another advantage of the split-thickness graft is that repeated "crops" may be cut from the same donor site at three to four week intervals when large quantities of skin are necessary to cover extensive defects.

Stent grafts are particularly useful in repairing defects in the mucous membrane of the mouth. In providing an epithelial covering over irregular surfaces and in cavities, it is often difficult to obtain firm, even pressure. This can be carried out successfully if the graft is applied over a mold cast

maintained, and when it is necessary to transfer a subcutaneous fat pad with the graft. To cover defects of the hand, either flexor or extensor, when tendons have been exposed, a flap containing a good subcutaneous fat pad is necessary, but a free graft should be used always when an adequate subcutaneous fat pad remains over the tendons. In cutaneous defects around the jaw or extremities, where the skin replacement is to be followed later by bone, nerve, or tendon surgery, a pedicle flap should be used since it will tolerate subsequent reopening or incision through which the underlying surgery must be approached. One thing must be remembered however, and that is that any flap on the hand or fingers is always bulky and clumsy as compared with a free graft. An adjacent cross finger flap may be preferable (Fig. 9-9).

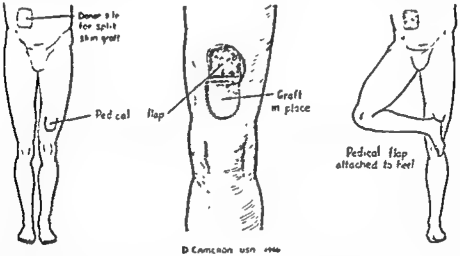


Fig. 9-10. Fresh avulsion of heel covered with direct pedicle flap from opposite thigh. Donor area of thigh closed by primary split-skin graft. (Courtesy Drs. C. J. Armstrong and L. H. Backus and U. S. Naval Hospital, Oakland.)

Whether the surgeon uses an open (Figs. 9-10 and 9-11) or tubed pedicle flap (Fig. 9-12) depends upon several factors. The open flap is quicker but is subject to contamination of its open pedicle. This can be minimized if the donor area and any unused exposed surface is covered with a split-thickness graft at the time of primary operation (Figs. 9-10 and 9-13). Small donor areas may of course be closed by suturing. The tubed pedicle flap however, is a closed mechanism throughout and is always the more desirable except for the additional time involved in its construction and transfer.

The safe proportion of length to width of pedicle flaps varies somewhat with the blood supply from which they are taken. Generally speaking however, a length of 2½ times as long as the breadth can be considered safe. If a longer flap is needed, it should be elevated in sections, leaving a central bridge attached until further blood supply develops in the ends of the tubed pedicle (Fig. 9-14).

The length of time necessary before a pedicle can be moved or divided varies considerably. The average tubed pedicle flap must be left in site after transfer to the defect being covered for about three weeks, but if the flap of skin being moved is large, or if the blood supply of the recipient

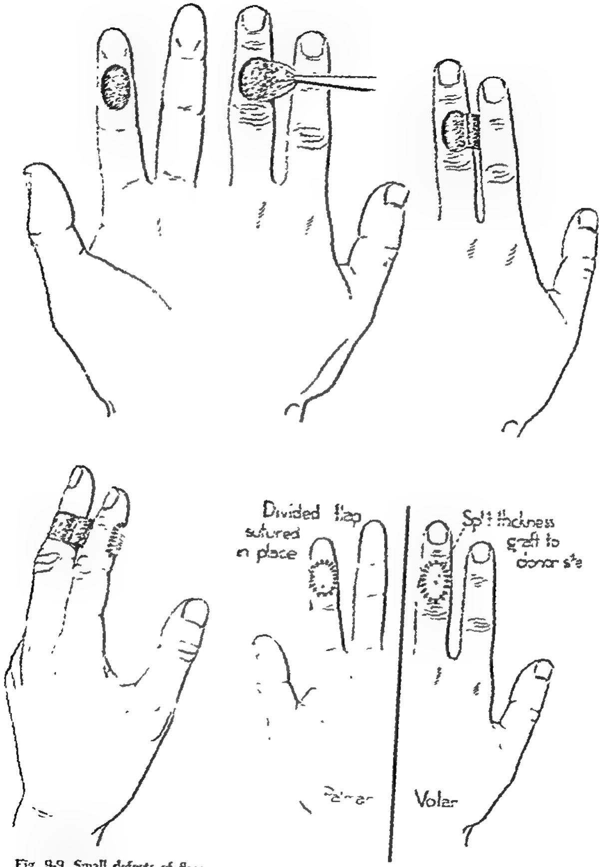


Fig. 9-9. Small defects of flexor aspect of fingers can sometimes be covered by using a cross-finger flap from an adjacent digit.

maintained, and when it is necessary to transfer a subcutaneous fat pad with the graft. To cover defects of the hand, either flexor or extensor, when tendons have been exposed, a flap containing a good subcutaneous fat pad is necessary, but a free graft should be used always when an adequate subcutaneous fat pad remains over the tendons. In cutaneous defects around the jaw or extremities, where the skin replacement is to be followed later by bone, nerve, or tendon surgery, a pedicle flap should be used since it will tolerate subsequent reopening or incision through which the underlying surgery must be approached. One thing must be remembered however, and that is that any flap on the hand or fingers is always bulky and clumsy as compared with a free graft. An adjacent cross finger flap may be preferable (Fig. 9-9).

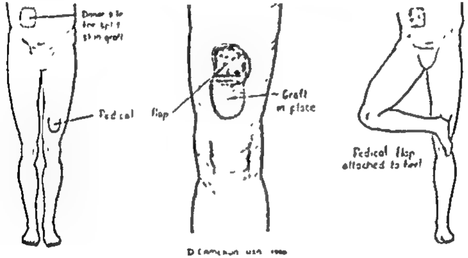


Fig. 9-10 Fresh avulsion of heel covered with direct pedicle flap from opposite thigh. Donor area of thigh closed by primary split-skin graft. (Courtesy Drs. C. J. Armstrong and L. H. Backus and U. S. Naval Hospital, Oakland.)

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area is poor the time must be lengthened in proportion. The new blood supply of the recipient area may be hastened by clamping off the base of the pedicle periodically, or by partially sectioning its base (delaying) and then closing this incision by suture.

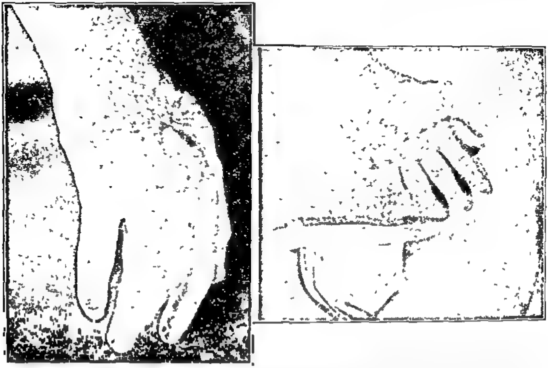

Fig 9-11 Healed gunshot wound of hand, needing new dorsal covering, and later, tendon and bone surgery. Right, scar excised and cutaneous defect replaced with direct pedicle flap Donor area closed by primary suture. This is the most rapid method of skin flap replacement, although the open flap becomes contaminated easily (Courtesy U. S Naval Hospital, Oakland)

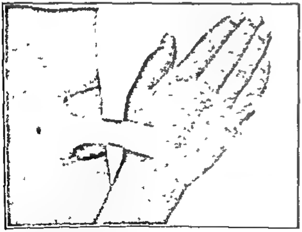

Fig 9-12. Replacement of dorsal skin and subcutaneous fat with tubed pedicle from abdomen prior to subsequent tendon grafts This method is slower, but much cleaner and safer than a direct flap (See Fig 9-9) (Courtesy Dr. Charles Steiss and U. S. Naval Hospital, Oakland.)

Donor areas must be chosen with thought. They must be taken from a location wherein the secondary deformity can be hidden by the patient's clothing. It must be remembered that hair-bearing areas must be avoided when transplanting pedicle flaps or free full-thickness grafts unless one desires to deliberately transfer hair with the skin, such as in the construction of a new eyebrow. The accidental transfer of hair-bearing skin must always be kept in mind. Patients will never thank a surgeon who inadvertently transplants a hair-bearing flap to the palm of his hand!

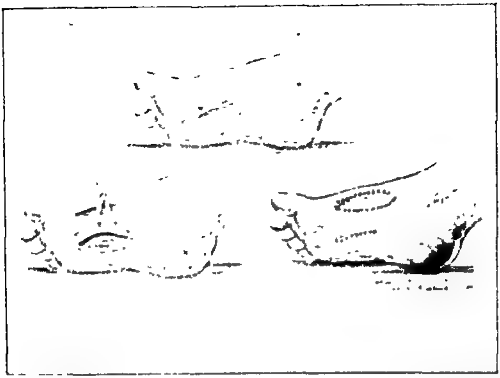

Fig 9-13 Painful scar on plantar surface of foot needs replacement with pedicle flap to withstand weight bearing After excision of scar, the defect was covered with bipedicle border flap from above, and donor area closed with split-skin graft (Courtesy U. S. Naval Hospital, Oakland)

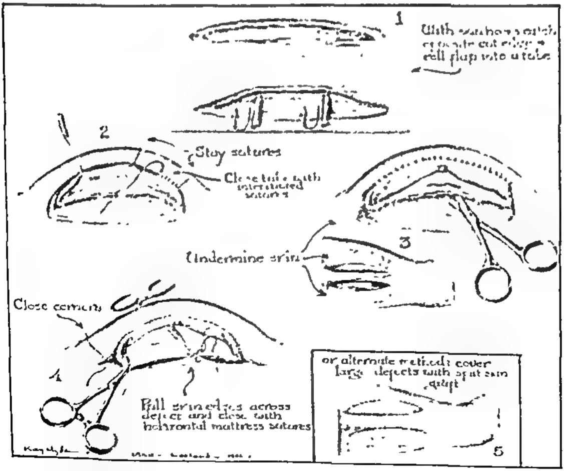

Fig 9-14 Technic of construction of tube pedicle flap Large donor areas should be closed with primary split-skin graft (Courtesy U S Naval Hospital, Oakland)

An attempt should always be made to select a graft that will match the area to be covered, both cosmetically and functionally. For small defects about the face, a free full-thickness graft from behind the ear or inner aspect of the arm will yield the best cosmetic result.

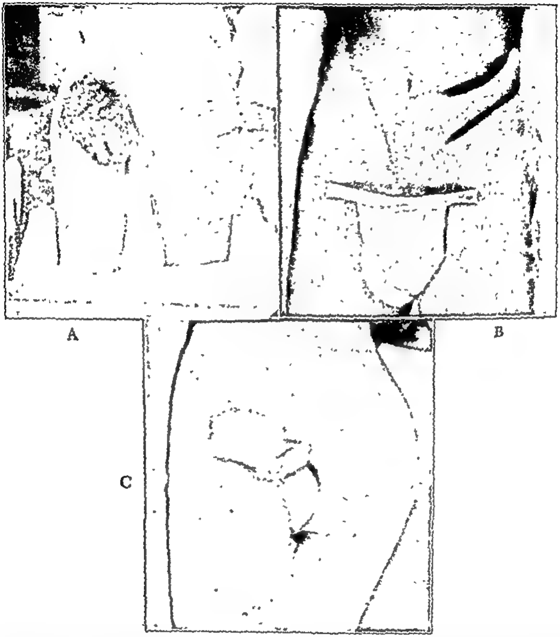

Fig. 9-15 A, large defect of buttock following shrapnel injury Tuberosity of ischium exposed in base of wound. Pedicle flap with fat pad indicated B, abdominal tube pedicle constructed and later transferred posteriorly into defect. C, covering completed. (Courtesy U S Naval Hospital, Oakland)

The largest donor areas from which to obtain split-thickness grafts are found on the abdomen, chest, back, and thigh. The normal total thickness of any split skin graft varies with the donor site, i.e., whether it is on the back, abdomen, or thigh, and whether a man, woman, or child. In other words, a graft cut with a dermatome set to 0.0024-inch thickness, from the back where the skin is relatively thick, would be carried into the sub-

cutaneous fat if it were taken from the inner aspect of the thigh on the same patient.

Homologous or isografts, that is, skin grafts taken from other individuals, are unsuccessful in light of our present knowledge, except in identical twins. This latter consideration will arise only in remote instances. However, thin Thiersch isografts may grow from one to six weeks before melting away. This fact may be of value in the temporary covering of an extensively burned individual who is too ill to withstand the surgery involved in autogenous skin grafting. While the success of this temporary graft must

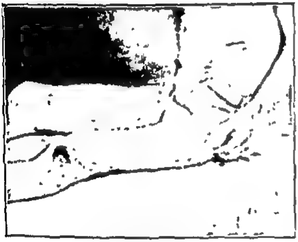

Fig. 9-16 Tube pedicle flaps can be moved from the abdomen to distant points by the "jump flap" method, using the hand or wrist as an intermediate host. This is a good procedure except that it usually places the patient in an awkward and uncomfortable position. (Courtesy Dr Charles Steiss and U S Naval Hospital, Oakland.)

Fig. 9-17 Extensive loss of full thickness of cheek, orbit, etc. Prepared arm flap will be rotated upward and turned 180 degrees on the pedicle so that the skin will become cheek lining and the subcutaneous fat pad will face anteriorly to be covered over with the border cheek skin for the most ideal cosmetic match. The tube pedicle acts only as a vehicle for nourishment of the lower end of the flap when transferred. The donor area beneath the tube has been covered with a split-skin graft. (Courtesy U S Naval Hospital, Oakland.)

be looked upon as a permanent failure, the transitory viable covering may tide over a critically ill patient until autogenous skin grafting can be done successfully. Zoo-grafting, the transfer of animal skin to humans, is spectacular but has not been successful.

Choice of skin grafts entails the following factors which must always be kept in mind:

1, the ease with which the defect may be covered;

2, the final cosmetic and functional result;

3, the comfort and safety of the patient during the period he is undergoing plastic surgical repair.

Planning the Type of Repair. In planning the repair of any cutaneous defect, the surgeon must visualize the final result and then decide upon the steps necessary to arrive at this end. He should apply his selected graft as early as possible, using the simplest method that will give the desired cosmetic and functional result. If it is necessary to use some type of pedicle flap, such a flap must be completely prepared prior to transfer before removing the pathologic lesion, whether it be a simple contracture or a neoplasm.

Methods of Cutting Skin Grafts. Small pinch grafts may be cut (Fig 9-7) with a scalpel after first lifting up the skin with a needle secured into a hemostat. Free full-thickness grafts are likewise cut with a scalpel (Fig. 9-8) after marking out the donor area around a leadfoil or other pattern of the defect to be covered. It must be remembered that this graft is to be removed free of all subcutaneous fat in order to insure growth.

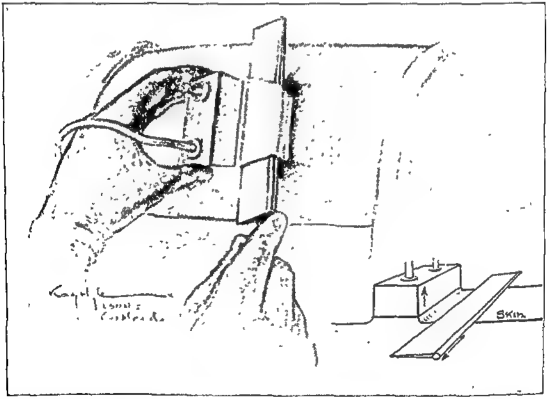

Fig. 9-18. Blair-Brown suction box for holding skin taut and slightly elevated for cutting large split-thickness grafts by free hand method (Courtesy U. S. Naval Hospital, Oakland)

Split-thickness skin grafts are most commonly removed by either of two well standardized technics. The simplest and most rapid method is to use the free hand razor method in which the graft is sliced off. Considerable refinement may be obtained by using the Blair-Brown suction box or vacuum retractor (Fig. 9-18) *which is slid along ahead of the cutting knife* blade. This retractor comes in 3 different widths and with practise, large grafts may be obtained quickly and easily. The second popular method is by use of the Padgett dermatome (Figs. 9-19 and 9-20). This instrument

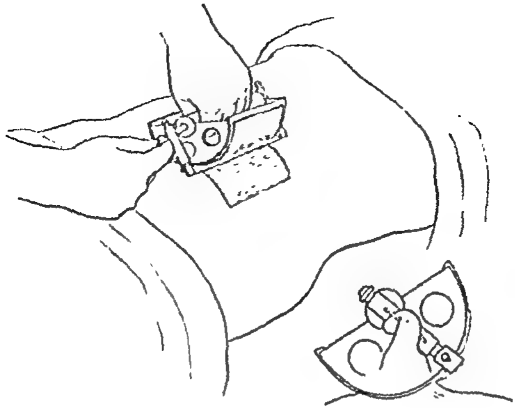

Fig 9-19. Method of cutting split-skin grafts of uniform thickness with Padgett dermatome. Thickness can be varied by adjusting screws.

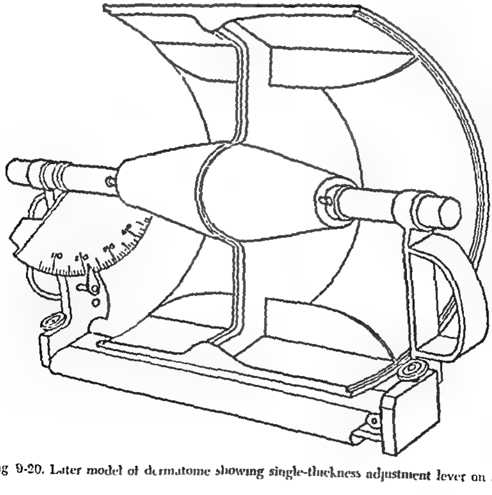

Fig 9-20. Later model of dermatome showing single-thickness adjustment lever on side.

consists of a drum, 4 by 8 inches in surface area, to which is attached a movable razor blade that can be set at a definite distance from the drum By varying this distance, grafts of various thickness may be cut with a high degree of accuracy and uniformity. A quick drying rubber cement is placed upon the drum and donor skin area. When placed in contact, the skin is held against the drum surface while the graft is then cut by a to-and-fro motion of the knife carrying lever.

Other mechanical instruments such as the Brown electric dermatome and the Barker Vacuotome should be mentioned for use in removal of split-thickness skin grafts. But because of more complicated machinery to get out of order and because their use is limited to certain donor areas, the free-hand method and Padgett-type dermatome will be found to have the greatest usefulness.

Irrespective of which method is used to cut the graft, the net skin graft is identically the same. All split-thickness, and free full-thickness grafts are transferred to the recipient area and secured in place with fine nonabsorbable sutures. A layer of plain petrolatum gauze, or 3 per cent xeroform-petrolatum gauze is then laid over the graft. Very fine mesh nylon silk is also ideal as the initial covering over the graft. This in turn is covered with sterile flat gauze pads, cotton waste, or abdominal pads. An ace bandage or bias-cut stockinette under mild pressure is then applied and, barring complications, the graft is not inspected for approximately one week. The dressing is then opened and all sutures, overlapping graft or hematomas removed. In case of split-thickness grafts, the pressure dressing is ordinarily applied for a second week, and with Wolfe-Krause grafts for one to two more weeks. When covering granulating defects that are commonly contaminated with *B. pyocyaneus*, earlier inspection of the graft is necessary. *Should excessive suppuration be found at the first dressing, a moist* boric acid dressing should be substituted until the area is clean.

Preservation of Skin Grafts. Extra skin may be cut at a preliminary operation. Any unused portion may be placed in a moist sterile gauze sponge. This is moistened with sterile physiologic saline solution and placed in a sterile glass jar. This is kept in a deep freeze and the autogenous split-thickness grafts so preserved, may be transferred successfully, after thawing, to the patient at subsequent operations over a period of at least three to four weeks.

Another simple method of preservation is to replace any unused portion of a split-thickness graft back on its donor site where it will grow. It can be pulled off easily and painlessly for about one week, and removed up to two weeks with the aid of local anesthesia. These small pieces are frequently useful in covering areas where all of the original graft failed to grow completely.

Preparation of Bed for Reception of Skin Grafts. All fresh surgical wounds, i.e., those following excision of healed scar contractures, neoplasms, or avulsions, present ideal bases upon which to place a skin graft. They are bacteriologically cleaner than any other defect.

Contaminated wounds must be treated both systemically and locally. Systemic treatment consists in the use of adequate doses of antibiotics. Local treatment includes removal of any necrotic tissue or oth

consists of a drum, 4 by 8 inches in surface area, to which is attached a movable razor blade that can be set at a definite distance from the drum. By varying this distance, grafts of various thickness may be cut with a high degree of accuracy and uniformity. A quick drying rubber cement is placed upon the drum and donor skin area. When placed in contact, the skin is held against the drum surface while the graft is then cut by a to-and-fro motion of the knife carrying lever.

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including bone sequestra. Following this, the wound is covered with sterile fine nylon silk (if unavailable, fine mesh gauze) and copious dressings which are kept constantly moist. Of the various solutions used, we have found saturated boric acid solution to be the most practical. The mild acidity of this solution appears to inhibit the pyocyaneus growth, a common contaminant in all chronic draining surface defects. It might be added that in an unusually wide experience with its use, so-called boric acid poisoning does occur, but is extremely rare.

These boric acid dressings should be changed every one to two days, until a firm red granulating bed is obtained. Any exuberant granulations can usually be flattened with a pressure dressing. If not, they may be excised with a sharp razor. As soon as grossly clean pink-red granulations are seen in all areas, the defect should be covered promptly with a skin graft.

It should be pointed out that chemical, electric and irradiation burns produce deep damage. These lesions, and old fibrotic granulating beds, should always be excised deeply, until a level of good blood supply is encountered. New healthy granulations ordinarily are permitted to form before proceeding with skin grafting.

METHODS OF CLOSURE OF SURFACE DEFECTS

In choosing the method most applicable for the closure of any surface defect, one must always visualize the ultimate result not only in terms of cosmesis and function, but also the technical problems involved. Simplicity is paramount.

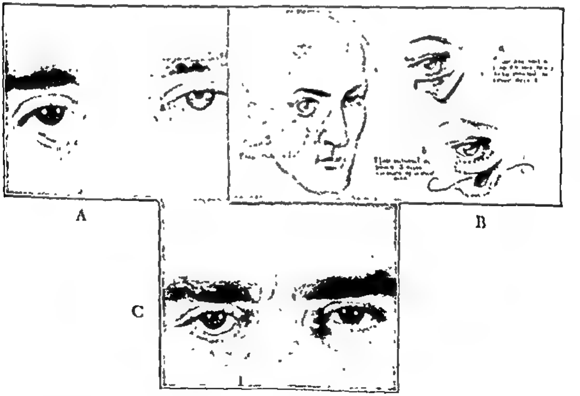

Fig 9-21 A, ectropion of lower lid secondary to deep scar contracture B, technic of correction by local interpolated flap This carries a good fat pad to provide correction of the subcutaneous loss C, early result Edema of flap disappears slowly (Courtesy U S. Naval Hospital, Oakland)

consists of a drum, 4 by 8 inches in surface area, to which is attached a movable razor blade that can be set at a definite distance from the drum. By varying this distance, grafts of various thickness may be cut with a high degree of accuracy and uniformity. A quick drying rubber cement is placed upon the drum and donor skin area. When placed in contact, the skin is held against the drum surface while the graft is then cut by a to-and-fro motion of the knife carrying lever.

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Whenever possible, all defects should be closed by primary suture. Wide undermining of adjacent skin borders will permit closure of amazingly large defects. Because skin is elastic and will stretch, the principle of multiple partial excision is invaluable (Fig. 9-53). The principle consists of partial removal of a cutaneous defect, especially those involving the face and neck, and suturing the borders after wide undermining of the adjacent skin flaps. After approximately three months, one finds the skin border flaps have stretched and loosened to normal tension. At this time, the process may be repeated and ultimately only a single fine scar line will result. From the cosmetic standpoint, this is far superior to replacement of the defect with a skin graft, which frequently does not match well in color.

Certain other defects, especially around the face, can be closed to cosmetic advantage by interpolating a local matching skin flap into the defect (Fig. 9-21).

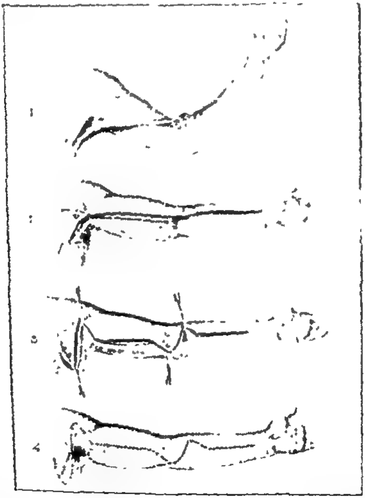

Fig. 9-24. Long scar contracture following ill-advised surgical incision corrected by double Z-plasty. (From Greeley. Am. J. Surg., 47: 101, 1945. Courtesy U. S. Naval Hospital, Oakland.)

Many linear scar contractures that cross flexor surfaces at right angles, can have this line of pull placed laterally so that its effect is lost, by the application of the Z-plastic principle (Figs. 9-22, 9-23, and 9-24). This maneuver can be executed with either single or multiple arms of the Z, depending upon the length of the contracting scar. The procedure is limited however, to the availability of adequate border skin flaps.

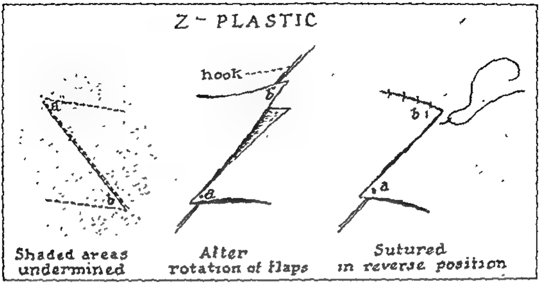

Fig. 9-22. Technic of Z-plasty.

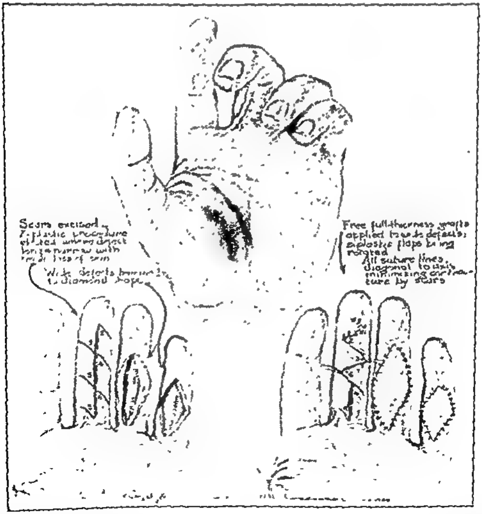

Fig 9-23. Methods for correction of flexor scar contractures of fingers When free grafts are necessary, full-thickness skin gives the maximum degree of elasticity and the best weight bearing surface. (Courtesy U S. Naval Hospital Oakland)

Larger defects that cannot be closed by mobilization of nearby surface coverings, must then by necessity be covered with a properly selected type of skin graft, i.e., the simplest variety that will correct the given problem (Figs. 9-25, 9-26, and 9-27).

Fig. 9-27. Large pigmented papillary nevus of face. Nevus excised and defect covered with free full-thickness skin graft from inner aspect of upper arm, giving optimum cosmetic result. (From Greeley: Surgery, 19:467, 1946.)

TRANSPLANTATION OF TISSUES OTHER THAN SKIN

The problem of building out depressions calls for the transplantation of either a soft or rigid living tissue that will be tolerated in its new bed.

Simple minor depressions may be eliminated by filling the defect subcutaneously with a dermal or so-called cutis graft. This consists of full-thickness skin from which the epidermal layer has been removed.

Free fat grafts have proven unsuccessful in most cases because of nearly complete absorption. Some operators advocate transplantation of free skin or fascia with a block of overlying fat attached. Even this procedure is of questionable success. The only certain method by which fat may be transplanted is by means of a pedicle skin flap, to which the normal subcutaneous fat pad has been left attached.

Free fascia lata grafts, rolled up to build out a depression, are usually replaced by fibrous tissue. Hence scar contractures in the area frequently ensue.

The most universal reliable structure used for correction of surface depressions is costal cartilage. This may either be autogenous, i.e., removed from the same patient, or preserved. It may be used in large pieces (Fig. 9-28 and 9-29) or diced into small bits and molded into shape. A still more practical method of building out contour depressions is to inject into defect, which has been loosened by blunt dissection, a mass of finely

Fig. 9-25 Extensive face scar, ectropion lower eyelid and partial loss of eyebrow after healed burn. Right, cheek and eyelid distortion relieved by replacement of scar with free full-thickness graft from inner aspect of upper arm. Eyebrow replacement with free full-thickness hair-bearing graft from left temporal area of scalp. (From Greeley. Surgery, 15:224, 1944.)

Fig. 9-26 Extensive pigmented verrucous hairy nevus of chest, neck and back. These large lesions are never malignant. Right, result after removal in five operations. Each defect covered with split-skin graft. Split-skin grafts do not give the best cosmetic result, but must be substituted *when extensive* defects are to be covered. (From Greeley. Surgery, 19:467, 1946.)

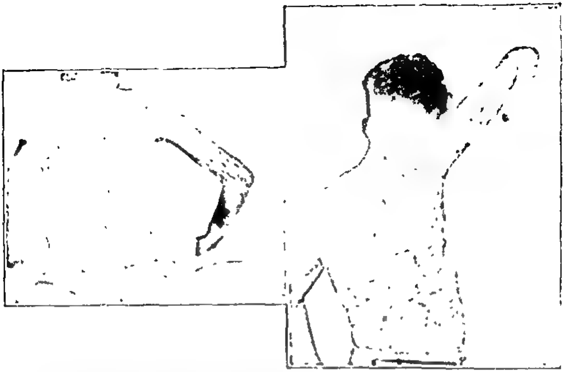

Fig 9-30. Extensive granulating defect of chest, axilla, upper arm, and forearm. Right, early healing after covering with many large split-skin grafts of intermediate thickness. (Courtesy U S Naval Hospital Oakland and Dr Charles Steiss.)

Fig 9-31 Linear scar contracture of neck. Right, correction by Z-plasty. (From Greeley. Surgery, 15.224, 1944)

grated cartilage. This material is obtained by reducing costal cartilage through a fine vegetable grater. This mass is then, as described by Penn, injected into the prepared cavity with a coarse syringe The chief disadvantage of block costal cartilage is that it will sometimes curl or bend and at times will undergo variable degrees of absorption.

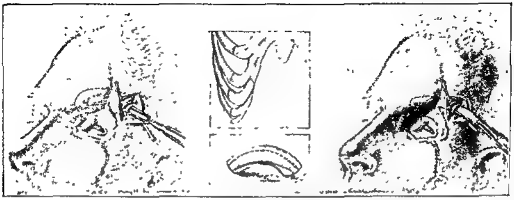

Fig 9-28 Correction of depressed supra-orbital ridge by subperiosteal insertion of autogenous costal cartilage graft. (Courtesy U S. Naval Hospital, Oakland)

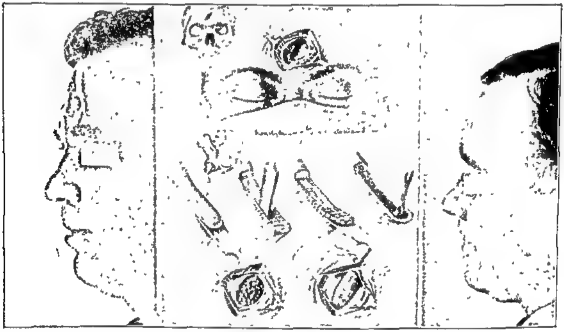

Fig. 9-29 Left, forehead depression following compound skull fracture Center, technic of obtaining and securing iliac bone chips Right, correction by subperiosteal insertion of iliac bone chips. (Courtesy U S Naval Hospital, Oakland)

Preserved costal cartilage is taken from fresh young adult nonseptic autopsy material. The perichondrium is removed and the cartilage placed in a jar containing 1 part of 1:1,000 aqueous merthiolate and 4 parts of sterile physiologic saline solution. The jar is then kept in a refrigerator. The solution must show negative cultures at repeated intervals and fresh solution should be placed over the cartilage every two or three weeks.

Bone grafts may be used in massive pieces or may be molded in a mass from small chips (Fig. 9-29). Because of its relatively simple accessibility and because it is a soft cancellous bone that vascularizes rapidly, the iliac crest is the most frequent source of bone grafts for use in plastic surgery (Fig. 9-29).

MANAGEMENT OF COMMON SPECIFIC PROBLEMS

Granulating Defects Following Burns and Avulsions. Split-thickness skin grafts of intermediate thickness grow well, and they give good functional results in most instances (Fig. 9-30). It must be remembered, however, that this may be the only type of covering that will grow successfully on granulations over tendons and muscles. The healed result may give rise to adhesions and limitation of motion. In this group of cases, the split-thickness graft must be looked upon as a temporary covering that has been utilized to convert the lesion into a closed wound. Later it may be necessary to replace this in a clean healed surgical field with a pedicle flap that can be transplanted successfully into this type of wound but might have failed earlier because of the contamination on a granulating surface.

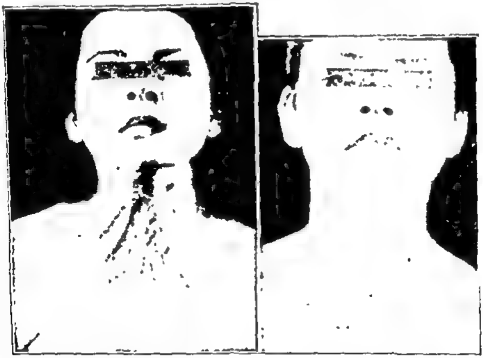

Fig. 9-33 Deep scar contracture of neck in which there was loss of subcutaneous fat pad. Larynx was caught in the scar. Right, replacement with tubed pedicle flap containing good subcutaneous fat pad (*From Greeley Surgery, 15*:224, 1944.)

Healed Defects. *Scar contractures of the neck* are corrected by first excising all scar tissue. In linear neck contractures (Fig. 9-31) the defect is corrected ideally by a Z-plasty. However, in broad defects replacement with a single thick split-thickness skin graft is necessary and is adequate when a good subcutaneous fat pad is present (Fig. 9-32). However, when the scarring is deep, the subcutaneous fat has been destroyed, and the larynx bound down with scar tissue, then a better functional result can be obtained if the defect is covered with a pedicle flap to which is attached a good fat pad (Fig. 9-33).

Axillary contractures, like neck contractures, are relieved by a Z-plasty when a single scar band involves only one axillary fold. Broad scarring however, must be excised and the defect covered with a thick split-thickness skin graft (Figs. 9-34 and 9-35).

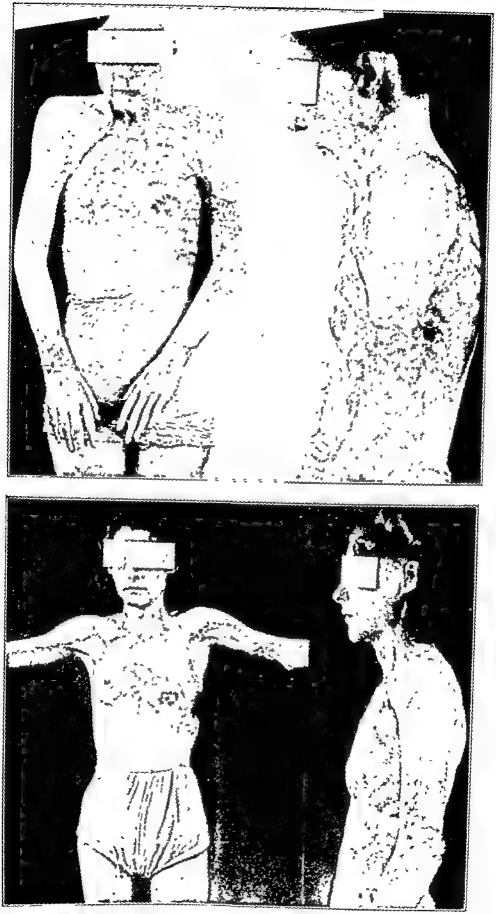

Fig. 9-32 Top, broad scar contracture of neck and axillae following healed burns Bottom, correction after excision of scar and covering defects with single split-thickness skin grafts. (From Greeley. Surgery, 15:224, 1944.)

Nasal tip and ala defects may be repaired with much less difficulty than commonly supposed. Contrary to popular belief, small defects of the ala and nasal tip can be filled in with free grafts taken from the ear helix. This provides skin covering and lining, with intervening subcutaneous fat and cartilage to give a good contour. The result is cosmetically ideal and the donor area of the lobule is closed by simple suture. The transplantation of subcutaneous fat with this free full-thickness skin graft is probably successful only because of the small segment of tissue that must be kept nourished until a new blood supply becomes established. The notching left in the ear donor site leaves little noticeable deformity after closure by primary suture. Larger nasal tip defects, however, must be reconstructed with either an interpolated flap from the adjacent nasolabial fold or a tubed pedicle flap from the neck (Fig. 9-8).

Fig. 9-36 Ectropion right upper and lower eyelids from healed burn scar contractures. Right, result after excision of scar and insertion of thin free full-thickness skin graft from prepuce. Smaller defects may be covered from redundant fold of opposite upper lid. (Courtesy U. S. Naval Hospital, Oakland.)

Intra-oral scarring, a frequent complication of compound jaw injuries, often obliterates the buccal sulcus so that dental prosthetic replacements cannot be worn. A simple procedure of correction is to first have the dentist construct a denture carrying the missing teeth. When completed, the obliterating scar is excised and the sulcus deepened (Fig. 9-37). The lower end of the prosthesis is then covered temporarily with Stent compound, to give additional bulk. This in turn is covered with a thin Thiersch graft taken from the hairless area of the upper arm, making certain that the raw surface of the graft is placed outward. The prosthesis, carrying the graft, is then slipped into the mouth, where the graft comes in contact with the newly created sulcus and the dental prosthesis serves to hold it in place until it grows. The prosthesis is removed in five to seven days, at which time the new sulcus will be found lined with a growing epithelial covering.

Scar contractures of hands, ideally, are corrected by single or multiple Z-plasties when there is available border skin (Fig. 9-22). When the defect is large, skin grafts must be utilized. Free full-thickness grafts serve best on flexor surfaces (Fig. 9-38) because they give the maximum degree of elasticity and withstand better the trauma of wear. For replacement of dorsal hand skin, thick, split-thickness grafts (Fig. 9-39) are adequate and are simpler to apply. The use of pedicle flaps (Figs. 9-10 and 9-40) is reserved for those cases having exposed tendons, or in whom secondary reopening of the skin covering will be necessary to complete underlying bone, nerve,

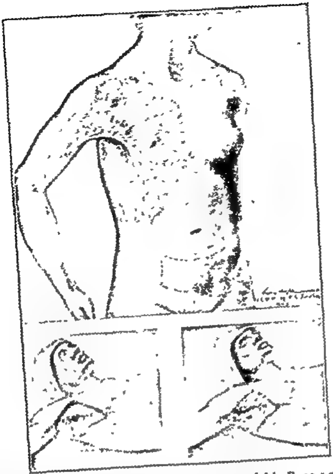

Fig. 9-34 Axillary contracture due to scarred anterior fold. Poor vascularity of tissue precludes Z-plasty in this case. Wide excision of scar and replacement with thick split-skin graft from abdomen. (Courtesy U. S. Naval Hospital, Oakland.)

Fig. 9-35 Wide chest-arm burn scar contracture of axilla. Correction after wide excision and replacement with thick split-skin graft. (From Greeley. Surgery, 15:224, 1944.)

Ectropion of the eyelid, commonly produced by contracting scars, may be relieved by Z-plasty when linear scarring is involved. Broad defects are usually covered with a thin full-thickness graft. The ideal sources of this graft are the skin of the opposite upper eyelid (for smaller lesions) or from behind the ear (Fig. 9-36).

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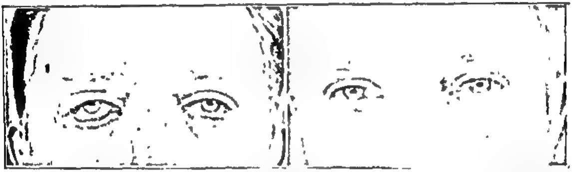

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or tendon surgery. In the latter group, pedicle flap coverings are necessary to withstand subsequent surgical trauma.

Syndactylism. Web finger operations (Fig. 9-41) usually involve covering of one finger with a skin flap from the other. The second digit of the web is then covered with either a Wolfe-Krause or thick split-thickness graft. The most important point to keep in mind is to avoid planning a straight linear suture line along the flexor surface of either finger. Such a line will predispose to a subsequent flexion contracture. The second important point is to provide adequate covering in the depth of the web to prevent a recurrence. Unless complicating deformities develop, the operation is usually done when the patient is 5 to 10 years of age. Earlier operations predispose to technical difficulties

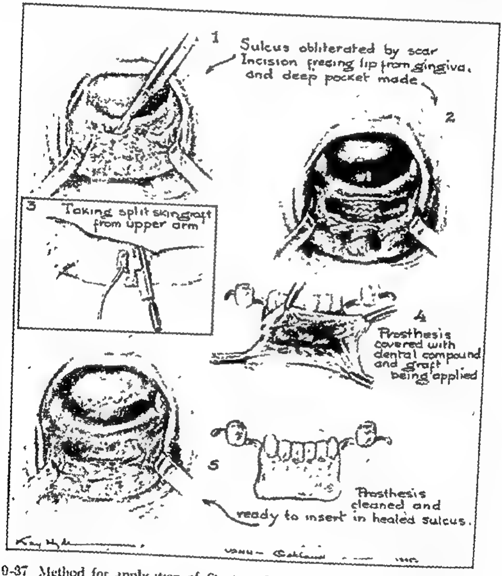


Fig. 9-37 Method for application of Stent graft over previously constructed dental prosthesis to deepen sulcus so that denture may be worn (From Greeley Illinois M. J., 89.216, 1946. Courtesy U S Naval Hospital, Oakland)

Polydactylism. This deformity, commonly manifested by an accessory thumb, is corrected by excision of the bony and skin appendage. The operation should be carried out in infancy and must always be preceded by x-ray films to determine which is the accessory of the double thumbs.

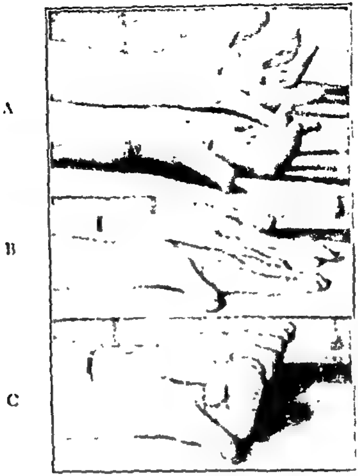


Fig 9-38. A, flexion scar contractures of fingers B and C, results after excision and covering with free full-thickness grafts (From Greeley Surgery, 15:224, 1944.)

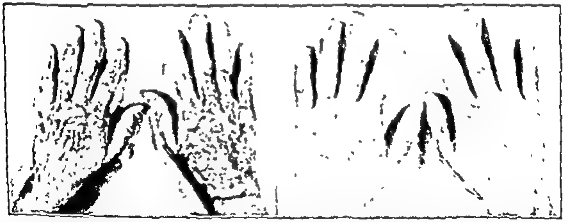


Fig 9-39 Dorsal scar contractures following healed deep second degree burns Right, after replacement with thick split-thickness skin grafts This type of graft functions adequately on the extensor surface of the hand and fingers and its technic is much simpler than when Wolfe-Krause grafts are used (From Greeley and Meherin S. Clin North America, 1651, Dec. 1943 Courtesy U. S Naval Hospital, Oakland.)

Reconstruction of the Thumb. The loss of a thumb may be very disabling because of inability to oppose against the remaining fingers In some cases it may be possible to pollicize an index finger, but in others it will be necessary to construct the digit from an abdominal tube pedicle (Figs. 9-42 and 9-43). For bony support, a graft of the twelfth rib is swedged into the

remnants of the first metacarpal bone after the tube pedicle has been attached to the thumb stump (Fig. 9-42).

Electric Burns. It must be remembered that electric burns produce deep damage (Fig. 9-44). Consequently all necrotic bone and tendon must be removed first. For the type of skin graft covering to be applied one will be guided by the indications for the given lesion.

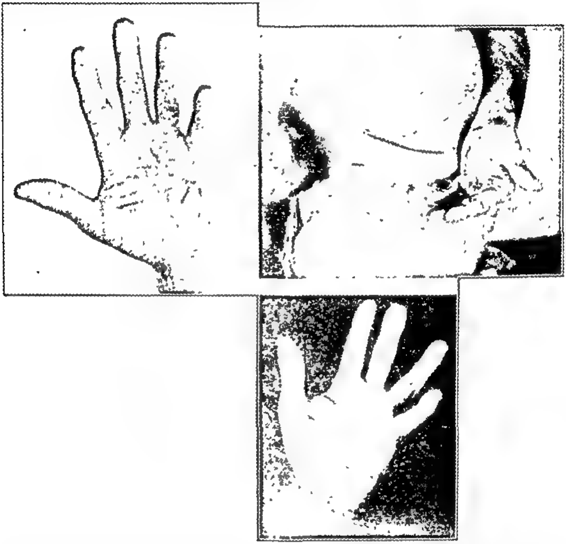


Fig 9-40 This scar contracture must be replaced with skin and subcutaneous fat in order that subsequent nerve and tendon surgery may be carried out beneath. Top right, tube pedicle flap ready for transfer Bottom, final result (Courtesy U S Naval Hospital, Oakland)

X-ray and Radium Injuries. Trauma of this type causes persistent pain, itching, or ulceration, and can be relieved only by wide excision of all damaged tissue back to an area of good blood supply. This procedure relieves all symptoms promptly and permanently. The resulting surface defect is then covered with a properly selected type of skin graft, usually a split-thickness or pedicle flap, because of their certainty of growing. It should also be borne in mind that radiation ulcers frequently break down into squamous cell carcinomas. Hence, suspicious ulcers of this type must be excised widely.

Plantar Warts. These lesions frequently are overtreated with x-ray or radium therapy. The radiation ulcer that occasionally follows may produce

serious technical problems in therapy. For those near the base of a small toe, sacrifice of the corresponding digit offers a simple treatment. The ulcer is excised, the toe "filleted," and the skin covering utilized to close the defect (Fig. 9-45 and Fig. 9-46). Loss of one of the small toes will

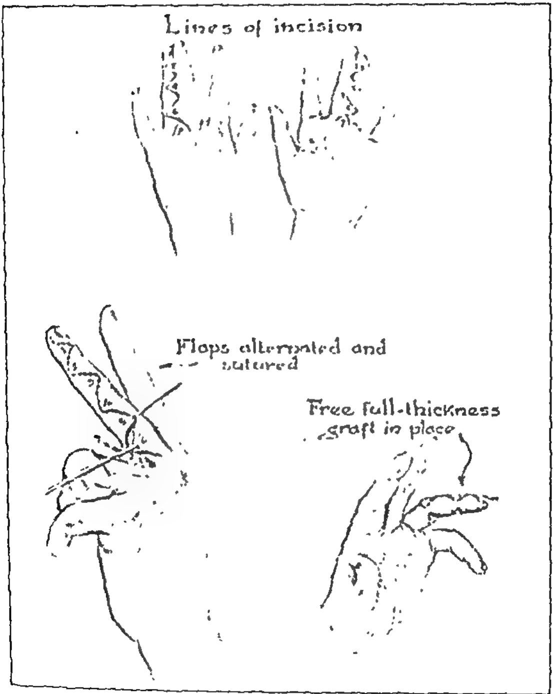


Fig. 9-41. Technic for correction of web fingers. (Courtesy U. S. Naval Hospital, Oakland.)

not destroy the balance of the foot. For lesions near the great toe, a flap from the opposite leg may be used, or for the heel, a direct flap from the opposite thigh. The chief criticism of either of these latter procedures, however, is the awkward position in which the patient must be held during the period of transfer (Fig. 9-47).

Carcinoma of the Skin. Neoplasms of this type are often treated ideally by excision Small defects are covered by primary suture or a properly selected type of skin graft.

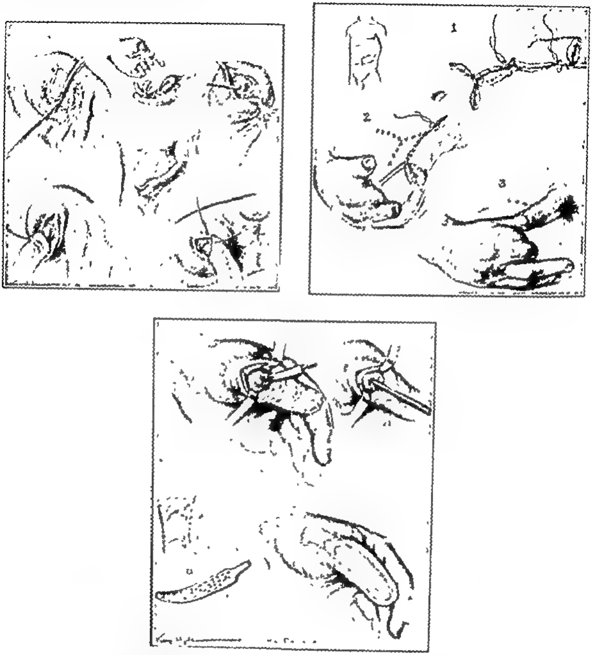


Fig. 9-42 Top left, reconstruction of thumb, using tube pedicle flap. Top right, for short reconstructions, a direct flap may be elevated, tubed, and transferred at once. Bottom, bony support obtained from twelfth rib Bone graft is swedged into hole drilled in metacarpal stump (From Greeley, Ann. Surg., 124 60, 1946 Courtesy U S Naval Hospital, Oakland)

Cancer of the lip, following wedge excision, may leave a defect that would produce a tight lip if sutured primarily. An ideal closure can be made with the Abbé-Estlander operation (Figs. 9-48 and 9-49). This is a satisfactory operation, from the cosmetic and functional standpoint, leaving two lips of symmetrical size, and does not interfere with the innervation of the orbicularis oris muscle as occurs in the older procedures which involve incisions around the angles of the mouth.

Scars and Keloids. Simple scars should be excised and the skin borders, after undermining, resutured accurately without tension. The sutures should be removed early but the skin edges must be supported for two to three weeks in order to avoid widening of the new soft scar. Occasionally, it will be necessary to construct Z-flaps in order to eliminate postoperative tension around unfixed areas such as the angle of the mouth (Fig. 9-50). Large defects, by necessity, may have to be covered with a skin graft (Fig. 9-25).

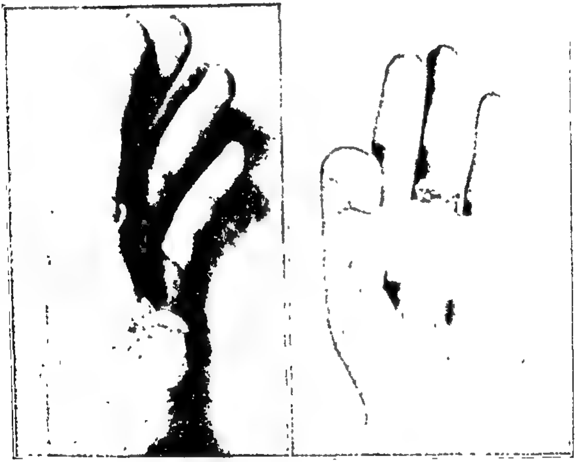


Fig. 9-43 Typical case of reconstruction of thumb (From Greeley Ann. Surg., 124:60, 1946 Courtesy U. S. Naval Hospital, Oakland.)

Keloids are often difficult to control. Large lesions (Fig. 9-51) are handled best by x-ray therapy given by a competent radiologist or dermatologist. Smaller keloids may be excised, but postoperative x-ray or radium therapy must be given in requisite amounts by a specialist in that field. This treatment should be started early, even 24 hours after operation.

Chronic Leg Ulcers. The majority of the chronic ulcers of the lower extremity fail to heal for the same underlying reason, i.e., poor blood supply in an area whose basic circulation is comparatively deficient even under normal conditions. Any such wound that has remained open for a long period of time becomes fibrotic, which in turn interferes further with an already damaged circulation. Consequently, before any local reconstructive measures can be undertaken, careful study of the underlying circulation must be made and these factors corrected first.

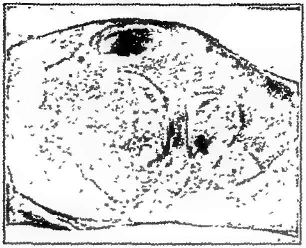


Fig. 9-44. Electric burn of knee. Note deep destruction including osteomyelitis of exposed bony structures. *Underlying pathology must be eliminated prior to application of permanent surface covering.* (Courtesy U. S. Naval Hospital, Oakland.)

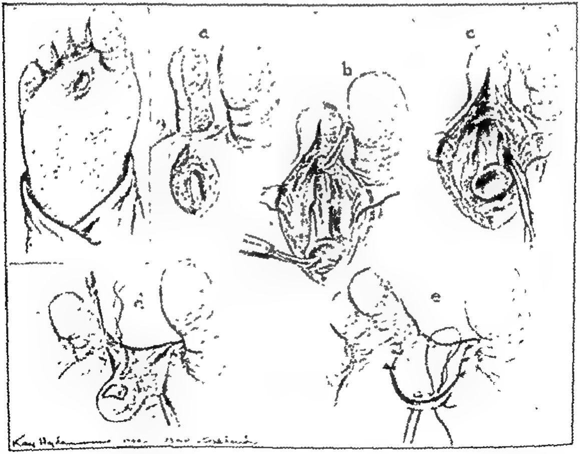


Fig. 9-45. Simple method of obtaining skin flap to replace radiation ulcer of sole following plantar wart therapy. Loss of one small toe will not impair balance of foot. (From Greeley. U. S. Nav. M. Bull., 45:827, 1945. Courtesy U. S. Naval Hospital, Oakland.)

Chronic Leg Ulcers

Chronic ulcers are frequently encountered following untreated third degree burns or traumatic loss of skin and subcutaneous fat. These wounds are superficial, are surrounded by scarring of the borders, and in the center is an area of fibrotic chronic granulation tissue. Scratching of this wound produces little or no bleeding.

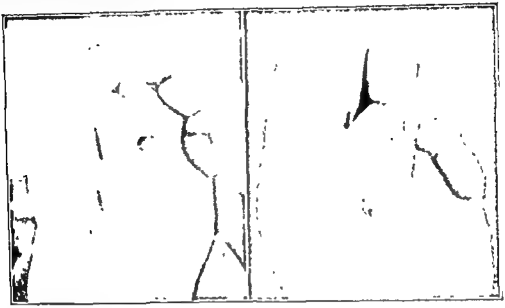


Fig. 9-46. Radiation ulcer of sole. Right, result following method described in Figure 9-45. (From Greeley. U. S. Nav. M Bull., 45:627, 1945. Courtesy U. S Naval Hospital, Oakland.)

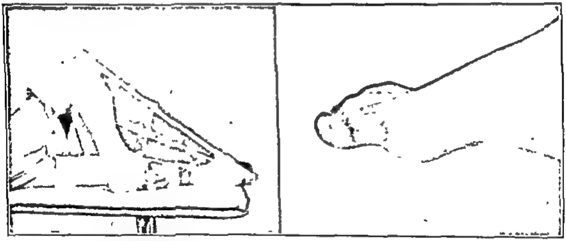


Fig 9-47. Radiation ulcer of great toe following plantar wart. Replacement by pedicle flap from opposite leg. This procedure is far more complicated and irksome for the patient than the method described in Figure 9-45, but is necessary for great toe and posterior sole and foot lesions (From Greeley. Am. J. Surg., 47:401, 1945. Courtesy U. S. Naval Hospital, Oakland.)

Treatment consists in wide excision of all chronic granulation tissue and surrounding scar back into an area of normal bleeding tissues. Practically all of these wounds can be covered with a split-thickness skin graft since normal subcutaneous fat is usually preserved. If a dry bed can be obtained, immediate skin grafting can be carried out. If there is considerable uncontrollable capillary bleeding, then one should wait until this is dry before proceeding. This may be accomplished by the temporary application of sterile dressings under moderate pressure and placing the patient on ade-

quate antibiotic therapy. After 24 to 48 hours the patient is returned to surgery and the dressings removed under anesthesia. Invariably a dry bed is observed at this time, thus making it possible to proceed with a successful skin grafting operation. An alternative procedure is to wait 7 to 10 days

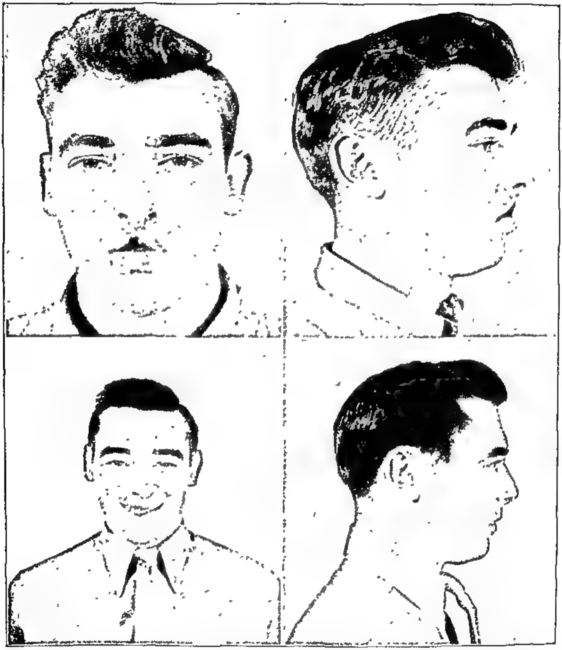


Fig. 9-48 Top, loss of substance of upper lip following gunshot wound Replaced by Abbé-Estlander procedure (reverse of Figure 9-49). This provides full thickness of lip tissue and vermillion border It does not disrupt the innervation to the orbicularis oris muscle, as occurs with operations about the angles of the mouth Bottom, final result. Dental prosthesis to replace missing teeth has been provided (Courtesy U. S Naval Hospital, Oakland.)

during which time a fresh firm granulating bed will develop. This also makes a fine recipient site upon which one can anticipate an excellent growth of a skin graft (Fig. 9-53).

Ulcers associated with compound fractures are always fibrotic, scarred, and frequently have sclerotic or necrotic bone in the base of the chronic ulcer. Treatment consists in removal of all scarring and elimination of any

bony sequestra if present. If the bone is merely sclerotic, one can sometimes improve the local blood supply by making multiple drill holes into the cortex or actually chiseling off some of the cortex into the Haversian system

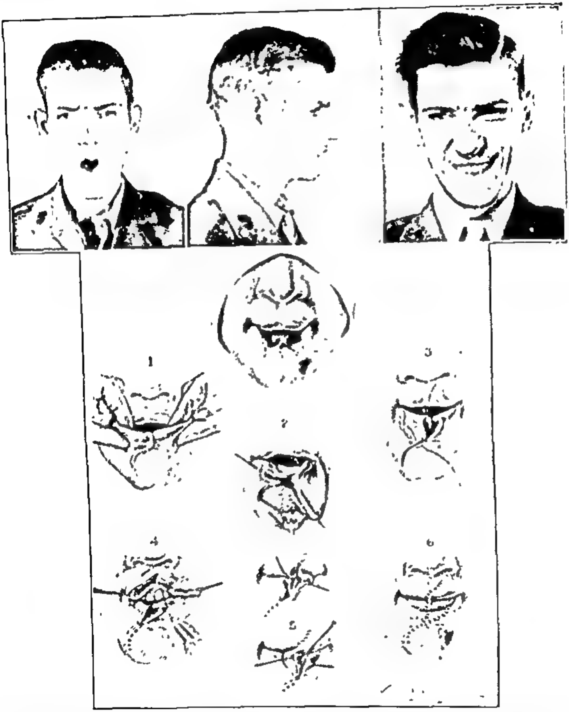


Fig 9-49 Tight lower lip following loss of substance from shrapnel wound. Top right, result after healing. Missing teeth replaced by dental prosthesis. Bottom, lower lip opened after removal of scar. Abbé-Estlander lip pedicle from opposite side sutured into defect, leaving coronal vessels in pedicle for blood supply Pedicle divided after 17 days. (From Greeley. Illinois M J, 89 216, 1946 Courtesy U. S Naval Hospital, Oakland.)

beneath. Fresh granulations with a good blood supply usually develop within the following 10 days. One can then cover this defect satisfactorily with a split-thickness skin graft. Otherwise it will be necessary to utilize a flap of skin and subcutaneous fat (Figs. 9-54 and 9-55).

Fig 9-50. Extensive scarring of face following compound fracture of mandible. Right, result after excision, wide undermining of skin flaps, and accurate suture of skin edges without tension. (Courtesy U. S Naval Hospital, Oakland)

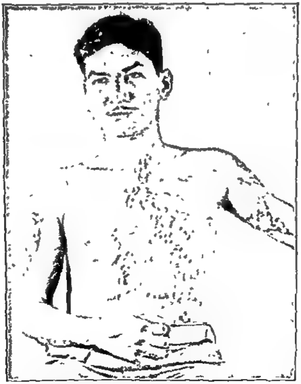


Fig. 9-51. Extensive keloid formation following burn. Scar hypertrophy softened and flattened by x-ray therapy. Smaller lesions on face should be treated by a combination of x-ray therapy plus excision *for maximum cosmesis* (*Courtesy U S. Naval Hospital, Oakland.*)

Varicose ulcers are always superficial and do not penetrate the deep fascia. Before local treatment can be undertaken, the varicosities must first be eliminated by ligation, stripping, or a combination of both. The leg should be elevated to reduce the edema. Lumbar sympathectomy may aid in selected cases.

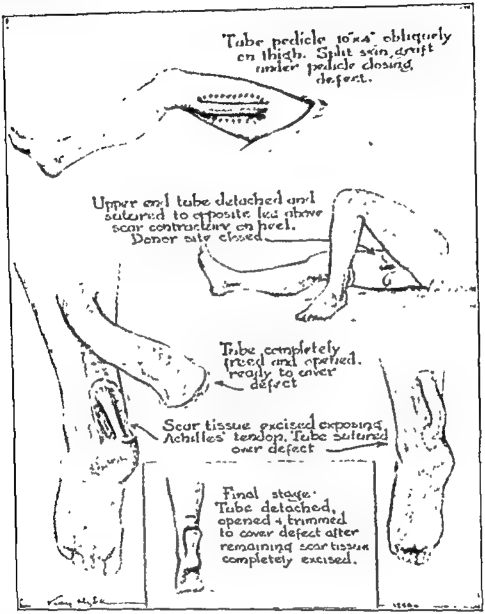
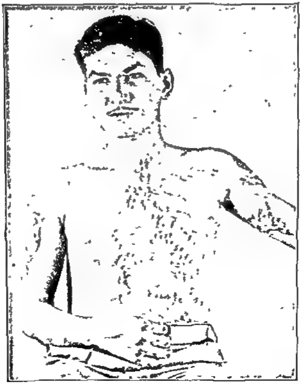


Fig 9-52 Defect over Achilles tendon needs skin and subcutaneous fat covering. Replaced by tube pedicle from opposite thigh Donor area covered with split-skin graft. This method is excellent when flaps are needed for defects of the leg. Flaps from the opposite leg are precarious because of their poor blood supply. (Courtesy U. S Naval Hospital, Oakland.)

Postphlebitic ulcers always destroy the deep fascia. Usually they are more extensive than varicose ulcers. It is not uncommon to see them encircle the ankle. Gross edema and infection are usually present, extending downward in some cases to involve the periosteum.

These patients should all have the circulation of the lower extremity tested with a lumbar block. If circulatory improvement is noted in this test, lumbar sympathectomy should be carried out prior to excision of the ulcer (Fig. 9-54).

Fig 9-50. [illegible] ig compound fracture of mandible. Right, result after excisic[illegible] and accurate suture of skin edges without tension (Cour[illegible])



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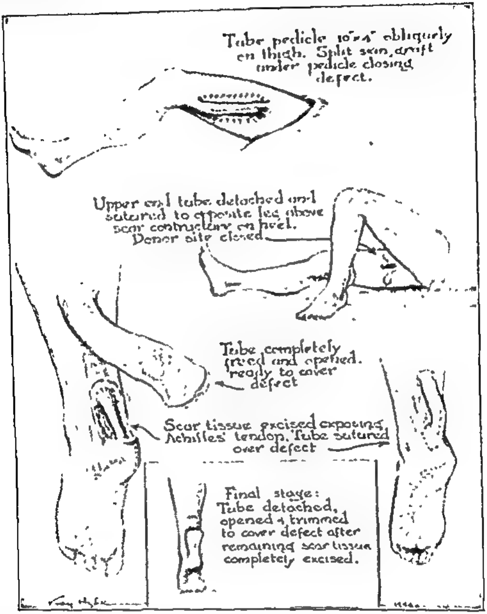

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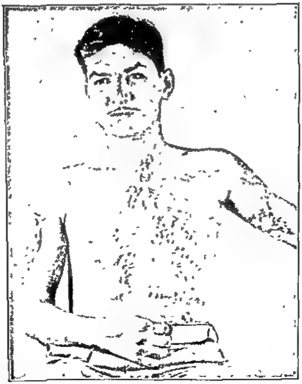

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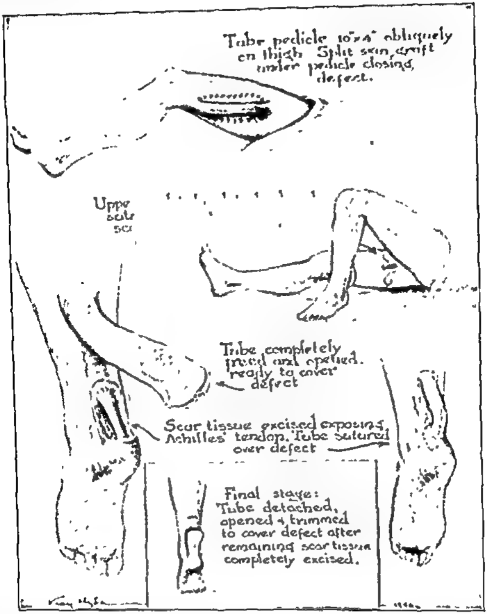

Fig 9-52. Defect over Achilles tendon needs skin and subcutaneous fat covering. Replaced by tube pedicle from opposite thigh. Donor area covered with split-skin graft. This method is excellent when flaps are needed for defects of the leg. Flaps from the opposite leg are precarious because of their poor blood supply. (Courtesy U. S. Naval Hospital, Oakland.)

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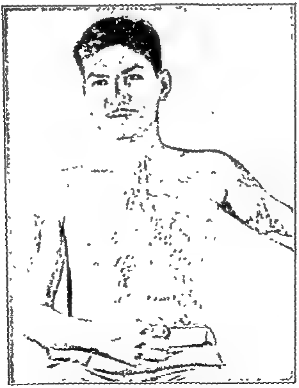
Fig. 9-50 Extensive scarring of face following compound fracture of mandible. Right, result after excision, wide undermining of skin flaps, and accurate suture of skin edges without tension (Courtesy U. S. Naval Hospital, Oakland.)



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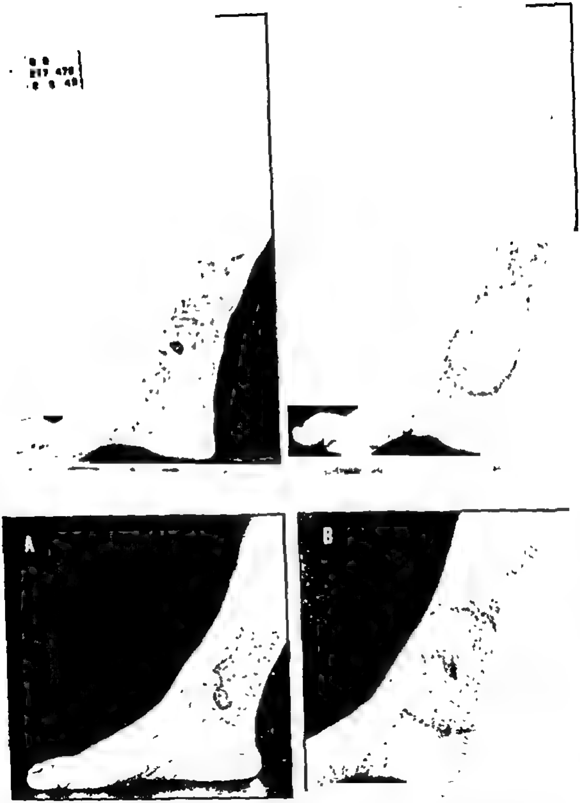

Fig 9-54. Chronic leg ulcers Top, chronic ulcer following compound fracture of tibia and fibula, 30 year old male Bottom, old thrombophlebitic ulcer These ulcers were treated by the method described in Figure 9-55 (Top from Greeley. S. Clin North America, 1551, Oct 1949)

In addition to the local covering, the postphlebitic syndrome must also be given consideration. It must be remembered that the original thrombosis of the deep veins produces ambulatory venous hypertension. This is because of the incompetent valves of the deep, superficial, and communicating systems of veins. To compensate for the venous deficiency, the patient should wear a two-way stretch elastic stocking. This stocking should have a heel, and extend well above the knee. It must be worn when the patient is ambulatory as long as there is any tendency for the extremity to swell.

Fig. 9-53. Chronic fibrotic ulcer of leg in 12 year old boy following a neglected burn which had occurred 10 months previously The ulcer with a large surrounding area was excised, one week later the defect was covered with a split-thickness skin graft The healed result is shown at the right (From Greeley Geriatrics, Vol 8, No 10, 1953.)

Arteriosclerotic ulcers always extend through the deep fascia. Because of extremely poor vascularity, extensive necrosis of the ulcer edges is usually seen. Exposed tendons and bone may likewise be encountered. Nearly all of this group are helped by a preliminary sympathectomy. Because of the extensive infection and necrosis present, the wounds must be débrided and cleaned up prior to excision

Following adequate preliminary treatment of varicose, postphlebitic and arteriosclerotic ulcers, they are then excised back into areas of better circulation. Drilling or decortication of the underlying bone may further improve the local blood supply While flap-covering the fresh open wound is usually desirable, it must be remembered that this variety of lesions is usually found in an older age group who cannot stand the rigors involved

Fig 9-54 Chronic leg ulcers Top, chronic ulcer following compound fracture of tibia and fibula, 30 year old male Bottom, old thrombophlebitic ulcer. These ulcers were treated by the method described in Figure 9-55 (Top from Greeley. S. Clin. North America, 1551, Oct 1949.)

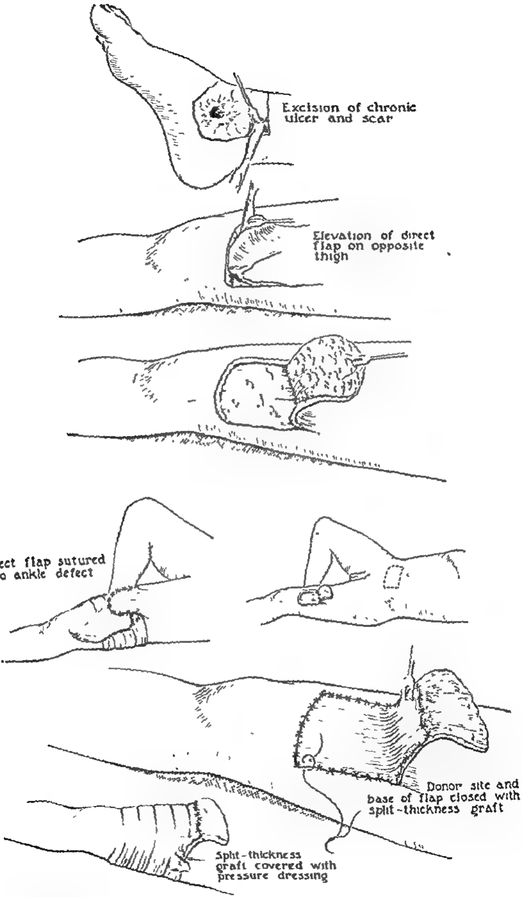

Fig. 9-55. Method of coverage of chronic leg ulcers with direct flap from opposite thigh. (From Greeley S Clin North America, 1551, Oct 1949)

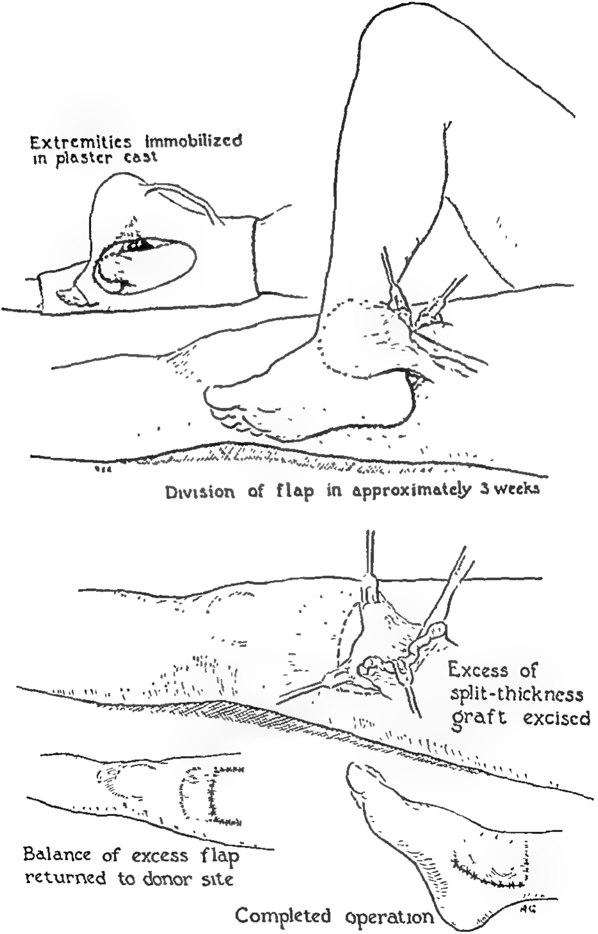

Fig 9-55 (cont) Further steps (From Greeley. S. Clin. North America, 1551, Oct. 1949.)

in a major pedicle flap transfer. As a compromise, one usually closes the open defect with a split-thickness skin graft. Although this may not give the most desirable covering, it is usually adequate providing the patient is reasonably careful.

Any chronic open wound that is associated with fibrosis, scarring, and poor blood supply, may ultimately degenerate into a squamous cell carcinoma. Most frequently are those associated with chronic radiation ulcers. Next in frequency are those developing in chronic ulcers following unhealed third degree burns, commonly known as Marjolin ulcers (Fig. 9-56). Squamous cell degeneration is occasionally seen in an old untreated varicose ulcer.

Fig. 9-56 Epidermoid carcinoma developing in site of old recurrent burn scar ulcer of 50 years duration Right, wide excision of carcinoma, removal of femoral and inguinal lymph nodes, and split-skin graft (From Greeley Surgery, 15 224, 1944.)

Treatment consists in wide local excision and closure with either a split-thickness skin graft or pedicle flap as indicated. The inguinal and femoral lymph nodes on the corresponding side should also be removed if palpable. If none can be felt, the patient must be kept under close observation for several years. Should any lymph node swelling occur at a later date, biopsy study is indicated, and if positive for metastatic carcinoma, resection of all femoral and inguinal glands must be carried out.

Decubitus Ulcers in Paraplegics. Lesions of this type fail to heal because of poor nutrition of the patient and because of poor circulation in and around the ulcer itself. Furthermore, most of the ulcers are complicated by chronic osteomyelitis or chronic osteitis of the projecting bone over which the breakdown always occurs. Hence a cure can be obtained only after the general nutrition of the patient is corrected by a high vitamin, high caloric, and high protein diet, adequate transfusions of whole blood and antibiotic therapy. All projecting bony points must be removed along

with the chronic ulcer itself and the resulting surgical defect covered with a local rotation flap containing an adequate subcutaneous fat pad. The donor site from which the flap is taken is then covered with a split-thickness skin graft. Once the wound is healed, it must be remembered that the patient is still a paraplegic and consequently must avoid prolonged pressure on these points in order to prevent future breakdown.

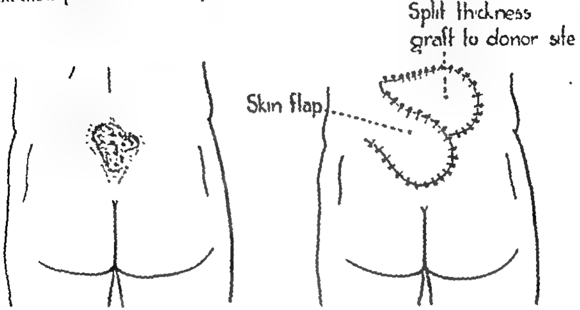

Fig. 9-57. Sacral decubitus ulcer. This must be excised widely through an area of good blood supply. The resultant surgical defect is closed by rotation flap from above, using a split-thickness skin graft to cover donor sites.

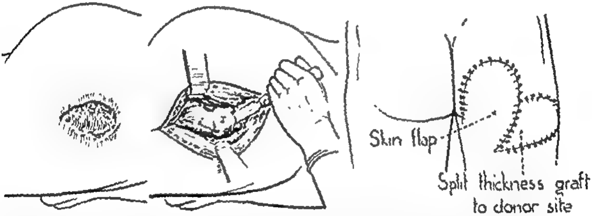

Fig. 9-58. Trochanteric decubitus ulcer developing over trochanter of femur. The ulcer is excised and the projecting trochanter removed with osteotome to eliminate infected bone as well as a "high point." The surgical defect is closed with rotation flap and the donor site is closed by split-thickness skin graft.

Methods of treating sacral, trochanteric, and ischial decubitus ulcers are shown in Figures 9-57 through 9-60.

Birthmarks. Included in these lesions are pigmented and vascular nevi. The small discreet, blackish-purplish pigmented nevus is apt to be the highly malignant melanoblastoma. This should be excised very widely and deeply. The large brown hairy nevus is almost never malignant and can be transected with impunity. Consequently, many lesions may be removed by the method of multiple partial excision (Fig. 9-61) or by a skin graft (Figs. 9-26 and 9-27).

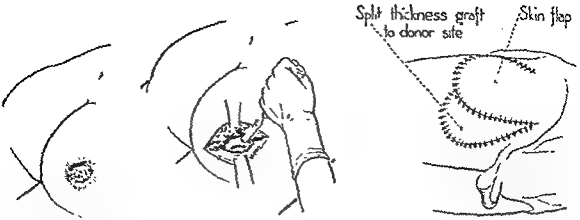

Fig. 9-59. Decubitus ulcer developing over tuberosity of ischium from prolonged sitting. The ischial tuberosity is removed with chisel after excising ulcer. The wound is covered with adjacent direct flap and the donor site is covered with split-skin graft.

Fig. 9-60. Occasionally an ischial decubitus ulcer w [illegible]
of the entire ischium. In such a case, after excision of [illegible]
the ischium with a Gigh saw. After removal of the is [illegible]
by primary suture because of the cavity made by elimination of the large underlying bony mass.

Fig. 9-61. Large benign pigmented nevus of face. The nevus was removed by multiple excision in three stages. Defect closed by suture after wide undermining of skin borders. This operation, when applicable, gives the best cosmetic result because of the matching face skin. (From Greeley, Surgery, 19,467, 1946.)

Vascular nevi may consist of a large cavernous swelling or the flat capillary port-wine mark. The former may be excised readily. Ordinarily they are not very vascular because of a large degree of fibrous element in

Fig 9-62 Cavernous hemangioma of upper lip Result 10 days after excision through intraoral aspect of upper lip is shown at right (From Greeley, Surgery, 19.167, 1946.)

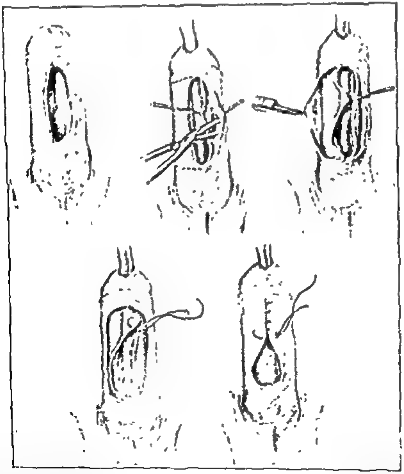

Fig 9-63. Traumatic hypospadius following shrapnel wound Simple method of closure. Preliminary cystostomy performed to keep field clean until healed. (Courtesy U. S. Naval Hospital, Oakland)

their substance. In doubtful cases, the vascularity may be diminished prior to excision by injection with sclerosing fluids or radiation therapy. The majority, however, can be excised as a primary procedure (Fig. 9-62).

The capillary nevus should be removed by multiple excision whenever

possible, since replacement with border skin gives the best cosmetic result. However, it may be necessary to cover the defects of larger lesions with a properly selected type of skin graft.

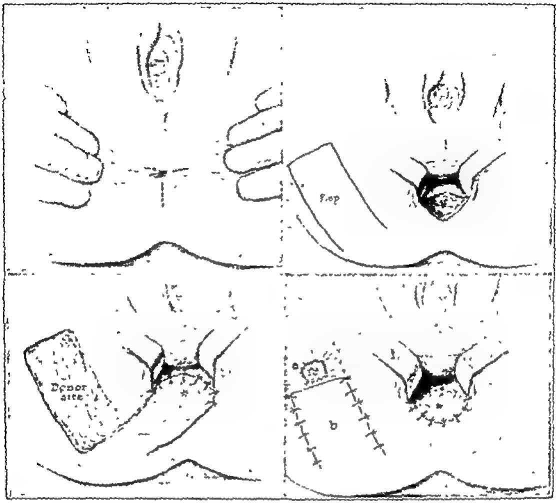

Fig 9-64 Anal stenosis following several previous local operations. Corrected by insertion of pedicle skin flap Preliminary colostomy performed to keep operation field clean. (From Greeley and Cole Surgery, 12(No 3):349-355, 1942)

Tattoos. These disfigurements may be artistic or accidental, and are treated similar to birthmarks The lesions are managed by multiple excision or replacement with a skin graft

More important however, is the prevention of accidental tattoos, by adequate scrubbing, under anesthesia if necessary, of all dirt, powder marks, and other foreign material from the open wound at the time of original injury. If not done then, the stains become fixed into the tissue quickly and permanently (Fig 9-3)

Congenital Absence of the Vagina. This not uncommon anomaly may be corrected very satisfactorily The plane between the rectum and bladder must be dissected open, up to the peritoneum The resulting canal is then lined with a split-skin graft placed over an adequate sized cylindrical mold of dental modeling compound balsa wood, acrylic, or similar substance. As with all Stent grafts, the raw surface of the skin must be placed outward. The mold is removed in one week but should be replaced after cleaning. Following this it is removed for daily cleansing, but should be worn in place for several months until the new skin lining has become d well

organized. Too early permanent removal may permit underlying fibrosis to cause some resultant stenosis.

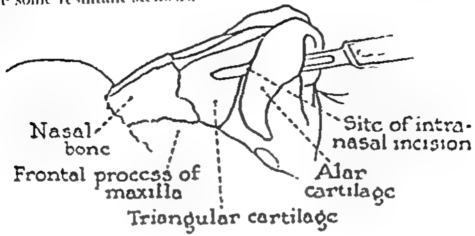

Fig 9-65. Showing anatomy of nasal arch and site of intranasal exposure of structures (From Greeley, Surg Clin. N. Amer., 22(No 1):233, 1944.)

Penile Hypospadias. Repair of this defect should always be preceded by cystostomy or perineal urethrostomy to divert the urine until the penile plastic has healed. Figure 9-63 demonstrates a type of closure that is applicable in many lesions. However, when a new urethral canal of any appreciable length is needed, the principle advocated by McIndoe, i.e., building a Stent graft over a catheter, produces an ideal result.

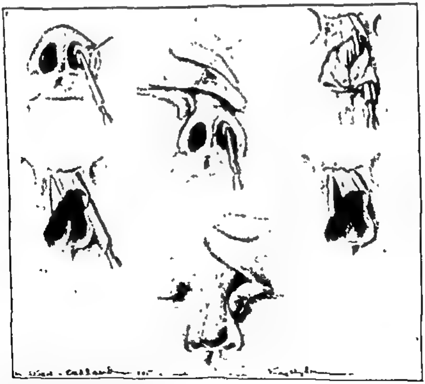

Fig 9-66 Technic demonstrating operative correction of healed left lateral nasal fracture deformity (Courtesy U S Naval Hospital, Oakland)

Anal Stenosis. Strictures of this type frequently follow operations for imperforate anus. The scarring resulting from previous procedures must be eliminated sufficiently to permit adequate opening of the anal ring (Fig. 9-64). The cutaneous defect is then covered with an adjacent pedicle flap of skin which will carry sufficient elasticity to allow for a normal opening.

possible, since replacement with border skin gives the best cosmetic result. However, it may be necessary to cover the defects of larger lesions with a properly selected type of skin graft.

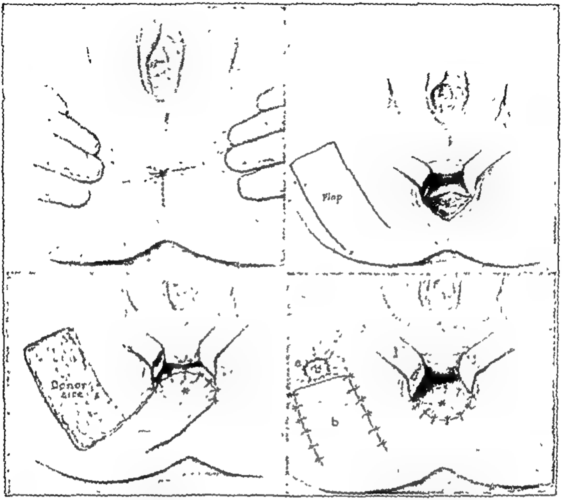

Fig 9-64 Anal stenosis following several previous local operations Corrected by insertion of pedicle skin flap Preliminary colostomy performed to keep operation field clean. (From Greeley and Cole Surgery, 12(No 3) 349-355, 1942)

Tattoos. These disfigurements may be artistic or accidental, and are treated similar to birthmarks The lesions are managed by multiple excision or replacement with a skin graft

More important however, is the prevention of accidental tattoos, by adequate scrubbing, under anesthesia if necessary, of all dirt, powder marks, and other foreign material from the open wound at the time of original injury. If not done then, the stains become fixed into the tissue quickly and permanently (Fig 9-3)

Congenital Absence of the Vagina. This not uncommon anomaly may be corrected very satisfactorily The plane between the rectum and bladder must be dissected open, up to the peritoneum. The resulting canal is then lined with a split-skin graft placed over an adequate sized cylindrical mold of dental modeling compound, balsa wood, acrylic, or similar substance. As with all Stent grafts, the raw surface of the skin must be placed outward. The mold is removed in one week, but should be replaced after cleaning. Following this it is removed for daily cleansing, but should be worn in place for several months until the new skin lining has become sof and well

NASAL DEFORMITIES

Nasal fracture deformities may be classified as lateral and depressed, the former following blows from the side and the latter from in front.

An accurate knowledge of the nasal architectural anatomy is necessary (Fig. 9-65) since practically all operations are executed by palpation through the endonasal route rather than direct vision.

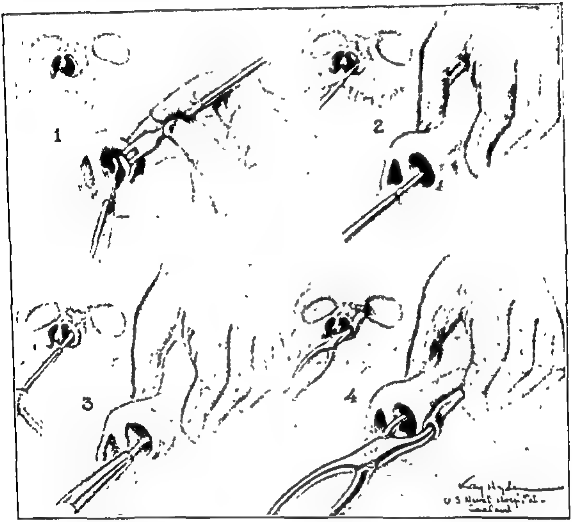

Fig 9-68 Technic of operative correction for healed nasal fracture with broad depressed arch (Courtesy U S Naval Hospital, Oakland)

In approaching either type of fracture deformity, the usual incision is made through the nasal mucosa beneath the alar cartilage and over the lateral or triangular cartilage on either side. The entire nasal arch is then exposed subperiosteally.

After exposure, the arch is cut with a saw and an osteotome (Fig 9-66). In case of a lateral deformity, one must resect a triangular segment at the base in order to create room to refracture the arch to the midline (Fig 9-67)

The depressed fractures are manipulated (Fig. 9-68) after saw cuts through the bases and septal attachments of the arch, so that the bases are brought inward and the arch upward. Position is maintained by one of several different types of external splints.

Fig. 9-67. Top, healed right lateral nasal fracture deformity. Bottom, after correction. (Courtesy U. S. Naval Hospital, Oakland)

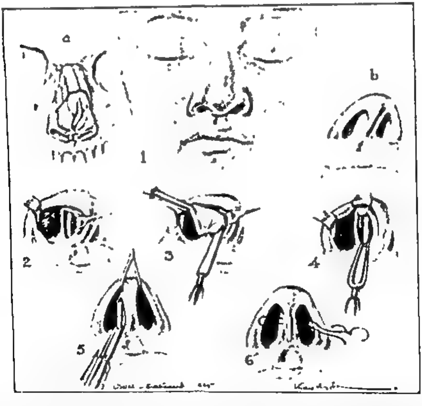

Fig 9-71 Top left, old fracture dislocation of lower end of septal cartilage Produces external deformity and nasal obstruction Bottom, displaced septal cartilage removed completely Obstructing spurs above eliminated by submucous resection. Septal cartilage replaced as free graft in normal central position Top right, result (Courtesy U. S. Naval Hospital, Oakland.)

Fig 9-69. Healed depressed compound nasal fracture deformity Correction of saddle deformity with carved segment of autogenous costal cartilage which has been inserted through a columellar incision. (Courtesy U. S. Naval Hospital, Oakland)

Fig. 9-70. Marked saddle deformity due to loss of septal support. Correction with carved block costal cartilage graft inserted through columellar incision. (Courtesy U. S. Naval Hospital, Oakland.)

The size of the new areola is first decided upon, usually approximately 1½ inches in diameter. This is laid out with a compass. An incision is made through this circle and the areola with its nipple removed as a free graft with a scalpel (Fig. 9-73A). It is cut just a little thinner than a free full-thickness skin graft. The central portion of the nipple is thinned out from its inferior surface. After removal, the nipple-areola graft is placed temporarily in a moist sterile saline sponge.

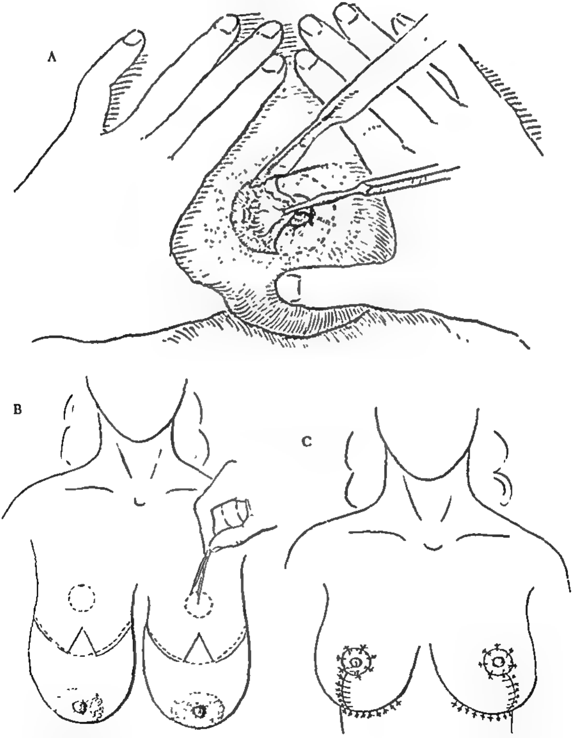

Fig 9-73 A, removal of areola with nipple as a free full-thickness skin graft B, redundant breast tissue excised as in a subtotal simple mastectomy. Removal of a wedge block of tissue in the center will give more rounded shape to breast when it is closed Note compass marking new site for areola C, all wounds have been closed by suture. Circular segment of skin excised for areola site and areola-nipple graft sutured in place as a free skin graft.

Saddle deformities may complicate depressed fractures, especially if the nasal septum has been damaged to the point of loss. This defect is corrected by the subcutaneous insertion of a carved costal cartilage graft or a shaped autogenous bone graft from the iliac crest, placed through an incision in the columella (Figs. 9-69 and 9-70).

Fracture dislocations of the nasal septum are often treated by submucous resection. However, a better plan is to dissect out the displaced cartilage (Fig. 9-71), following which it is replaced in the midline, thus giving both a good airway and normal nasal tip support. Septal cartilage replacement, however, must only be utilized when it has not been severely distorted in shape by previous trauma.

PLASTIC SURGERY OF THE BREAST

Two general types of operative procedures should be considered for the correction of breast hypertrophy. Neither procedure incidentally will have any appreciable effect upon future lactating function since pathologically speaking these large breasts are essentially big fatty tumors with very little breast tissue in their substance.

Before proceeding with either type of operation, the new location of the nipple and areola must be established. This is best done prior to surgery with the patient standing erect. Markings are made with brilliant green. Of several methods for locating the nipple site, the procedure advocated by Gillies and McIndoe (Fig. 9-72) is simple and quite reliable. Certain variations will occur because of different individual statures but the markings can be adjusted by eye to compensate for this.

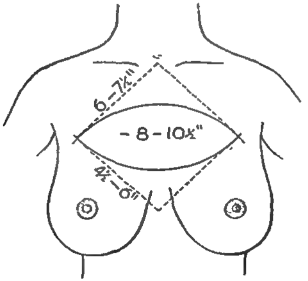

Fig 9-72 Method of determining approximate site of nipple.

The operation is carried out under general anesthesia with the patient in a semisitting position. Because the operation is long, an adequate quantity of whole blood is given by transfusion during surgery.

The simplest operation consists in subtotal resection of the redundant hypertrophic breast and free transplantation of the areola with the nipple.

The next step is to excise the redundant breast tissue (Fig. 9-73B). After securing hemostasis, the skin edges are closed in the transverse axis (Fig. 9-73C). The second breast is treated in a similar fashion.

After both breasts have been closed, the new areola location is established from previous markings. Using the same compass setting, a circle is drawn through the skin. This segment of skin is removed carefully with a scalpel (Fig. 9-73B), leaving the base of the corium with its rich network of capillaries as an ideal recipient site upon which to suture the free areola-nipple graft (Fig. 9-73C).

After all sutures have been inserted, a soft rubber drain is brought out through the lower portion of the wound. The drain is removed in 12 to 24 hours. A bulky pressure dressing is then applied. Sutures are removed from the graft in approximately 1 week and from the skin edges in 10 days. Pressure should be reapplied to the nipple-areola grafts for an additional 7 to 14 days in order to prevent venous congestion. The breasts themselves should be supported for at least one month following surgery.

Although the operation of partial amputation and free transplantation of the nipple is simplest, it usually leaves a semiflat pancake-shaped breast and its use should be reserved chiefly for older patients who are more interested in removal of the heavy bulk rather than the cosmetic result.

The second type of operation follows the plan originally described by Biesenberger. This is technically more difficult to perform and is occasionally complicated by all or partial necrosis of the nipple. It does however give a well rounded breast that is cosmetically superior. It is a one stage operation and is more desirable for younger to middle-age patients.

The first step consists in marking out the new nipple location as described above (Fig. 9-72). Incision is made around the newly established size of the areola (Fig. 9-74A). The incision is then carried downward to the inframammary fold and thence laterally in each direction (Fig. 9-74B). Through these incisions the skin covering of the breast is undermined in all directions. This process of denudation must be extensive. It is carried laterally to a point near the anterior axillary fold and superiorly to the infraclavicular level to expose the pectoral fascia. The medial portion is undermined to a lesser degree. The inferior portion of the breast is likewise uncovered.

The breast blood supply is chiefly dependent upon the internal mammary artery. With this in mind, the lateral and inferior portions of the breast are now excised (Fig. 9-74C). After securing hemostasis, the lower portion of the breast is rotated laterally and superiorly (Fig. 9-74D) following

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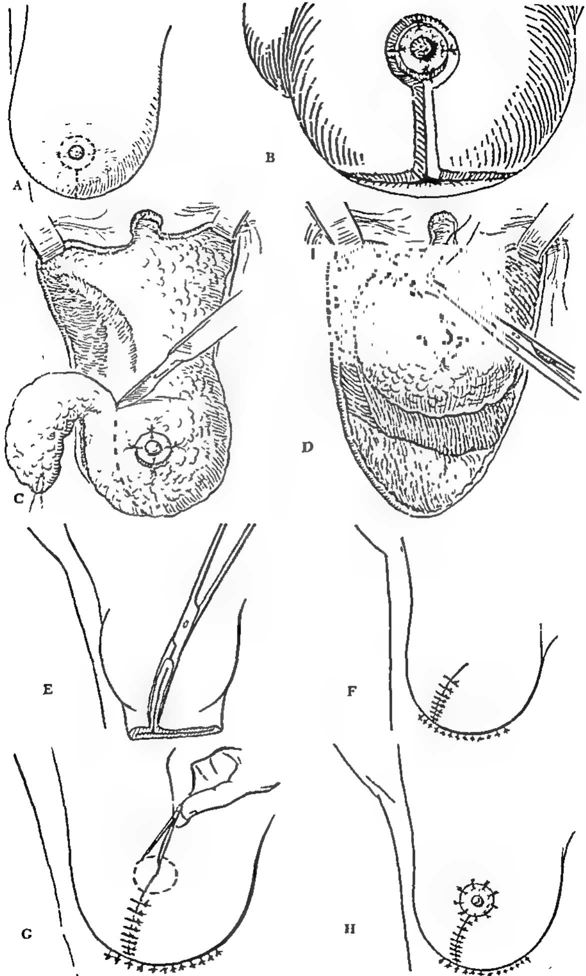
Fig 9-74 A, reduced size of the areola is marked out with a compass and the skin incised accordingly B, the skin incision is next carried down to the inframammary fold and thence laterally in each direction The skin covering is then undermined extensively in all directions but to a lesser extent medially. C, after denuding the breast of its skin covering [illegible] breast and the excess skin trimmed out in the oblique axis A curved intestinal clamp across the skin simplifies accurate excision. F, skin flaps have been sutured G, the new nipple site is identified and marked with a compass This disk of skin is excised and the areola-nipple component brought through the opening. H shows areola sutured into new location.



For legend see opposite page.

10

FRACTURES

J. Albert Key

PRINCIPLES IN THE OPERATIVE TREATMENT OF FRACTURES

Most simple fractures *can and should be treated by conservative methods* because exposure of the fracture by operation adds the danger of infection to damage already present. However, some fractures are not amenable to conservative treatment and in these, operations are necessary if a satisfactory result is to be obtained. In others conservative treatment may fail or operative treatment may be the treatment of choice. In my opinion, an open reduction and internal fixation by a competent bone surgeon in a modern operating room is a much safer and a more satisfactory method of treating fractures of the extremities than is the transfixion of the fragments by multiple pins inserted through the skin and the reduction and fixation of the fragments by these pins and some form of apparatus designed for this purpose.

In the operative treatment of fractures rigid asepsis must be observed because the surgeon is dealing with damaged and partially devitalized tissues which have little resistance to infection and with bone in which infection tends to persist once it has become established.

The operation should be planned carefully and the material necessary for the proper internal fixation of the fragments should be at hand before the operation is started. Only noncorrosive metals should be used in the tissues and only one type of such metal should be used in the same wound. That is, one should not use stainless steel and vitallium or even different types of stainless steel screws, plates, nails or wires in one operation, because electrolysis between the metals of different composition may occur and lead to absorption of bone.

Care and forethought in positioning the patient and the extremity on the operating table and in draping the extremity in such a manner that it can be manipulated freely may add much to the ease and success of the operation. In operating upon fractures of the lower extremities a fracture table which affords mechanical traction may be advisable and should be used when this is desirable. Local or general anesthesia may be used depending upon the choice of the surgeon.

The fracture is exposed through the most direct route, avoiding important nerves and blood vessels when possible and using muscle planes and lines of cleavage in the tissues when possible in order to avoid any unnecessary damage to tissues. The so-called nontouch technic is not used, but the surgeon and especially his assistants avoid placing their hands in

which it is sutured to the pectoral fascia and the base of the breast pedicle, using 000 chromic catgut. After shaping the breast, the skin flaps are draped down over the reconstructed breast. The excess skin is trimmed off (Fig. 9-74E) and the wound edges sutured (Fig. 9-74F).

The site for the new areola-nipple location is next identified and marked out with the compass. A corresponding disk of skin is removed (Fig. 9-74G) and the periphery of the areola sutured in place (Fig. 9-74H). A Penrose rubber drain is brought out through the lower portion of the wound but should be removed in 24 hours. A copious fluffed gauze pressure dressing is finally applied and secured with bias-cut stockinette or a large Ace bandage.

Sutures are removed from the areola edge in 7 days but the skin sutures are usually left for 10 to 14 days. A well fitted brassiere must be worn day and night for one month and for at least an additional month when up and about during the daytime.

10

FRACTURES

J. ALBERT KEY

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the wound unless for a definite purpose which cannot be accomplished as well by instruments. Tissues are dealt with as gently as possible and excessive traction is avoided. Bleeding points are ligated and muscles, tendons and nerves are repaired with silk as fine as is consistent with the strength required for the purpose.

After satisfactory reduction and internal fixation of the fragments and the repair of the soft tissues the wound is washed out with a supersaturated solution of sulfanilamide or sulfathiazole, or of both, and some of this solution is left in the wound. The wound is then closed in layers using fine silk except for the skin where plain catgut may be used if a cast is to be applied over the wound. In most instances the extremity is immobilized in a plaster cast after the operation is completed.

If tissue damage has been excessive or if for any other reason infection is feared, penicillin is given in moderate doses for a few days after the operation until the danger of infection has passed. An ounce of prevention here is worth many pounds of cure.

THE UPPER EXTREMITY

Fractures of the Clavicle. Open reduction of a fracture of the clavicle is rarely indicated, because fractures of this bone usually unite promptly; even when union occurs with considerable deformity, satisfactory function may be expected.

Occasionally, however, a satisfactory reduction cannot be obtained and maintained; in such instances open reduction may be advisable. As the bone is subcutaneous throughout its length the exposure of the fracture is relatively simple. The patient lies supine on an ordinary operating table with the affected shoulder close to or slightly overhanging the edge of the table. The operative field is so draped that the arm on the affected side can be manipulated by the surgeon. An incision about 2 or 3 inches long and parallel to the clavicle is made just below the bone and opposite the site of the fracture. The incision is carried down through the skin, subcutaneous tissue and fascia to the bone. The upper margin of the incision is retracted to expose the fracture site and the proximal end of the humerus (shoulder) is forced outward, backward and upward and if necessary the reduction is facilitated by grasping the ends of the fragments with small bone forceps, towel clips or Ochsner forceps and pulling them into position. If soft tissue lies between the fragments this is excised or pushed or pulled back into its normal position. When the reduction is effected its stability is tested. Usually it will be found that some form of internal fixation is indicated. In a long oblique fracture it may be sufficient to bind the fracture site with one or two loops of small stainless steel wire or with chromic catgut or silk, holes may be drilled and the ends of the fragments tied together with one of the above materials.

A very satisfactory method is the introduction of a stiff (Kirschner) wire into the medullary cavity across the fracture site (Fig. 10-1). This wire is introduced through a drill hole made either proximal or distal to the fracture and usually the drill hole is made through a separate small incision directly over the bone. The wire may be left projecting through the

skin and removed about four weeks later when union is sufficiently advanced or it may be cut off, pushed down into the drill hole and left in situ as an intramedullary peg spanning the fracture site. The wound is closed in layers without drainage and the extremity immobilized for a few days in a Velpeau dressing. In about a week the skin sutures are removed and a dressing which affords as much external fixation as necessary is applied for four or five weeks longer. The type of dressing will vary with the efficiency of the internal fixation. With an efficient intramedullary wire no external fixation may be necessary after the first week or so. In most instances a plaster yoke should be worn for four or five weeks.

Fig. 10-1. Left, fracture of the clavicle with marked displacement in which conservative treatment failed to maintain reduction. Right, after reduction and fixation with an intramedullary wire which projected through the skin and was removed after union was firm

Fractures of the Scapula. Very rarely indeed is operative reduction of a fracture of the scapula necessary. In one instance I encountered a fracture through the neck of the scapula in which the glenoid was displaced backward and in which manipulation had failed to effect a reduction.

With the patient lying upon the face and opposite side and so draped that the affected extremity could be manipulated, the site of the fracture was exposed by an incision just below and parallel to the spine of the scapula. The infraspinatus muscle was partly detached and retracted to expose the fracture. A large blunt dissector was forced between the fragments and the displaced fragment was levered outward and forward into a satisfactory position. It was quite stable and no internal fixation was necessary. The wound was closed without drainage and a Velpeau bandage was applied. Immobilization was discontinued after about four weeks.

Fractures of the Proximal Third of the Humerus. This is a fairly common injury but in most cases it can be treated satisfactorily with a hanging cast with or without manipulative reduction. Occasionally, however, displacement cannot be sufficiently corrected by manipulation and an open reduction is advisable. This is especially apt to be the case, in adolescents. in epiphysial separations of the proximal portion of the humerus, which are several days old, or in fractures in older patients in which the proximal fragment is comminuted and rotated in the glenoid.

The patient is placed supine upon an ordinary operating table with

the affected shoulder near the edge of the table and the operative field is so draped that the arm can be manipulated.

An incision about 4 inches long is made in the anterolateral aspect of the shoulder. This begins at the margin of the acromion and extends downward parallel to the fibers of the deltoid muscle. The incision is carried down through the subcutaneous tissues and fascia to expose the deltoid muscle. The fibers of this muscle are separated and retracted, care being taken not to injure the circumflex nerve which lies just beneath the muscle in the lower third of the incision and extends around the proximal portion of the shaft of the humerus coursing at right angles to the incision. *Consequently, the deep fibers of the deltoid in the lower third of the* wound are separated very gently by blunt dissection and retraction in this area should not be excessive.

After the circumflex nerve has been identified the muscle is retracted to expose the fracture site. Usually the distal fragment will be found to be displaced upward and inward. With the elbow flexed downward traction is made on the arm and the proximal end of the distal fragment is grasped with medium sized bone holding forceps and pulled outward until a satisfactory reduction is effected. The stability is then tested.

Usually some internal fixation will be indicated. It is difficult to fix the fragments with loops of wire or screws, but this can be easily accomplished by drilling two or more stiff Kirschner wires through the proximal and into the distal fragment (Fig. 10-2). These wires are inserted blindly through the skin on the superior and lateral aspect of the shoulder and penetrate the marrow canal and cortex of the distal fragment. After they are in place they are cut off about 1 inch from the skin and the ends are bent 90° to prevent them from drifting into the tissues.

The fracture is then inspected and if the fragments are in satisfactory position and stable, the wound is closed in layers and the extremity is immobilized in a Velpeau dressing for about 10 days. At the end of this time the sutures are removed, a dressing is placed over the projecting ends of the fixation wires and a light hanging cast is applied. Gentle swinging exercises are begun and the wires are pulled out about four weeks after the operation and the hanging cast is removed about six weeks after the operation.

Fractures of the Greater Tuberosity of the Humerus. In most instances of isolated fractures of the greater tuberosity of the humerus the fragment is not sufficiently displaced to render operative reduction necessary. However, if the separated fragment is drawn up beneath the acromion open reduction and fixation is necessary. The patient is placed supine on an ordinary operating table and the operative field is so draped that the affected extremity can be manipulated freely.

An incision about 3 inches long is made on the anterolateral aspect of the shoulder. This begins at the margin of the acromion and extends directly downward. It is carried down to the deltoid muscle and the fibers of this muscle are separated by blunt dissection to expose the greater tuberosity of the humerus which lies beneath the muscle. Care is taken not to injure the circumflex nerve which lies just beneath the muscle and may cross the incision in its distal portion. The margins of the wound

are retracted and the separated loose fragment is looked for in the upper portion of the wound or it may be displaced upward beneath the acromion. When it has been located the loose fragment is drawn downward and the arm abducted and rotated until an accurate reduction is obtained. The fragment is then held in position with a small sharp rake retractor and sutured

Fig 10-2 Top left, fracture of the proximal portion of the humerus in which conservative treatment failed Top right, after open reduction and fixation with intramedullary wires which projected through the skin and were removed after union was firm. Bottom, fracture of the proximal portion of the humerus in a child in which conservative treatment failed Fixation by a projecting medullary wire after open reduction.

in place or fixed with a nail or screw or with one or two Kirschner wires which are passed through the intact skin to pin the loose fragment to the humerus. The wires are then cut off about an inch from the skin and ends are bent 90° to prevent them from drifting into the tissues. The extremity is then immobilized in a Velpeau dressing which is left in place

for about 10 days. Then the sutures are removed and the projecting ends of the wires are covered with a dressing and a light hanging cast applied and pendulum exercises are begun. The wires and cast are removed about three weeks later and the exercises are continued and use is resumed gradually.

Fracture Dislocation of the Shoulder. This injury consists of a complete fracture of the proximal third of the humerus and an anterior dislocation of the head of this bone. It is a severe injury and in my experience open reduction is the treatment of choice and usually this is combined with internal fixation.

The patient is placed supine on an ordinary operating table with the affected shoulder near the edge of the table and the field is so draped that the arm can be manipulated. Under general anesthesia an incision about 6 inches long is made from the middle third of the clavicle down to the insertion of the deltoid. This incision is carried down to the mesial border of the deltoid muscle and this is separated from the lateral border of the pectoralis major muscle leaving the cephalic vein on the mesial side. If this vein is injured it is ligated.

The superior end of the incision is turned outward along the clavicle for about 2 inches and the mesial portion of the anterior deltoid is detached from the clavicle and this muscle is retracted outward to expose the fracture in the humerus and the dislocated head of this bone. The greater tuberosity may be avulsed or the external rotator muscles may be stretched across the glenoid.

The capsule of the shoulder is incised and the head of the humerus is grasped with bone holding forceps and manipulated back into the glenoid while traction is made on the arm. If the long head of the biceps tendon interferes with the reduction this may be cut and repaired after the reduction is accomplished. The fracture is then accurately reduced by traction and manipulation of the arm in abduction and the stability is tested by bringing the arm to the side with the forearm across the chest. Usually it will seem advisable to use some form of internal fixation. If the fragments are suitable one or two loops of stainless steel wire or screws may be used to fasten them together. In recent years I have used two or more Kirschner wires passed through the intact skin on the top and side of the shoulder and drilled downward through both fragments. If the head of the humerus is not stable in the glenoid a wire may be drilled through the head and into the glenoid. The wires are cut off about an inch from the skin and bent 90° to prevent them from drifting into the tissues.

When the stability of the fragments is satisfactory the wound is closed in layers, the mesial portion of the deltoid being reattached to the clavicle and the extremity is immobilized in a Velpeau type dressing with the hand on the opposite shoulder. At the end of three weeks the dressing is removed and a hanging cast is applied to the arm and shoulder exercises are encouraged. The hanging cast is removed about three weeks later and use of the arm is encouraged.

If the head is found to be free in the tissues or to retain so little attachment that its blood supply is destroyed, the head is removed, the proximal end of the shaft is rounded off and placed in the glenoid and

the tuberosity fragments with their muscle attachments are fixed to the proximal portion of the shaft and the shoulder is treated as described in the preceding paragraph.

Fractures of the Shaft of the Humerus. Most of these fractures can be satisfactorily treated by traction or with a hanging cast. But occasionally because of interposition of soft tissues or a lesion of the radial nerve or for some other reason open reduction is advisable (Fig. 10-3).

Fig 10-3 Left, fracture of the shaft of the humerus in which conservative treatment (hanging cast) failed Right, after open reduction and fixation with a plate and spica

The patient is placed supine on an ordinary operating table with the forearm across the chest and the arm supported by a large sand-bag and so draped that it can be manipulated. The site of the fracture is exposed by a lateral incision which follows the anterior border of the deltoid in the proximal third of the arm, and follows the lateral intermuscular septum in the middle third and in the lower third swings forward along the anterior border of the brachioradialis muscle. Any or all of this incision is used as needed for adequate exposure.

The radial nerve lies in a groove behind the humerus in the middle third of the arm and then swings forward to pierce the external intermuscular septum and course downward and inward between the brachio-

radialis and the brachialis anticus muscles. In any operation on the shaft of the humerus in the middle or lower third of the arm this nerve should be identified and carefully guarded from injury.

The incision is carried down to the fracture site usually dissecting anterior to the external intermuscular septum and the ends of the fragments are exposed. The incision is enlarged upward or downward as necessary and the fracture is reduced by traction and manipulation and the fragments may be held in place with a clamp or bone holding forceps while suitable internal fixation is applied.

Fig 10-3 (cont.) Same as Figure 10-3, right Lateral view

Depending upon the character of the fracture, the fragments may be fixed with noncorrosive wire, screws or plates. When the internal fixation is satisfactory the radial nerve, if exposed, is inspected and replaced in its bed in such a manner that soft tissue is interposed between the nerve and metal or bare bone. The incision is then closed in layers and a hanging cast is applied. Pendulum exercises are encouraged and the cast is worn for from four to six weeks when union is sufficiently firm to permit the patient to begin to use the arm.

Instead of the above the fracture may be reduced by closed manipulation or by open operation and the fragments fixed by a medullary pin which can be introduced through a drill hole in the lateral surface of the proximal fragment (greater tuberosity) or in the posterior surface of the distal fragment just proximal to the olecranon fossa. When an intramedullary nail is used in the humerus it is important that distraction be prevented. This can be done by a rather tight sling beneath the elbow and forearm and by active exercises of the shoulder and arm muscles.

Separation of the Internal Epicondyle of the Humerus. This lesion is not infrequent in older children and adolescents and may complicate a dislocation of the elbow. The apophysis of the internal epicondyle is pulled off and displaced downward by the flexor muscles which are attached to it. The patient is placed supine on an ordinary operating table with the arm abducted and supinated and supported on an arm board or a side table and so draped that it can be manipulated.

The site of the fracture is exposed by a longitudinal incision about 3 inches long which lies just anterior to the internal condyle of the humerus. This incision is carried down through the deep fascia to expose the smooth bare area of bone on the mesial surface of the internal condyle from which

the epicondyle has been detached. The ulnar nerve lies behind the condyle and usually is not displaced or exposed and need not be disturbed. The torn flexor muscles are then separated and the avulsed fragment is sought. It usually lies in the elbow joint just mesial to the coronoid process of the elbow. When found it is lifted out and by flexing the elbow it is usually possible to replace it in its original position where it is fixed by a suture or small nail or a Kirschner wire. A very satisfactory method is to drill a short Kirschner wire through the intact skin and the detached fragment and then into the lower end of the humerus. The end of this wire which protrudes through the skin is bent 90° to prevent it from wandering into the tissues.

The wound is then closed in layers after snugging the loose fragment down against the bone and taking a few sutures in the muscle to hold it in position. The extremity is immobilized in a plaster cast or plaster mold with the elbow flexed to about 60° and pronated to relax the muscles attached to the loose fragment. At the end of four weeks the Kirschner wire is removed and a week or so later the cast is removed and the patient may begin to use the arm.

Fractures of the Internal Condyle of the Humerus. This is an injury of adult bone in which the internal condyle including much if not all of the trochlear is broken off and displaced upward and forward. The ulna goes with the loose fragment and the head of the radius may be displaced with the ulna. The fracture involves the trochlear surface of the joint and anatomic reduction is necessary for the restoration of normal function. As a rule reduction can be accomplished by traction and manipulation, but the displacement tends to recur. For this reason open reduction and internal fixation are indicated (Fig. 10-4).

The patient is placed supine on an ordinary operating table with the arm abducted and supinated and supported on a side table or arm board. The extremity is so draped that it can be manipulated. A longitudinal incision about 5 inches long is made over the internal condyle of the humerus and carried down through the deep fascia to expose the loose fragment. This is retracted and the fracture is inspected. The ulna nerve is identified behind and usually bound to the condyle, or it may be dis-

moved and the patient can carry the arm in a sling and begin to exercise the elbow.

Fractures of the Capitellum or External Condyle of the Humerus. This is a relatively rare injury in children and I know of no case in an adult. The capitellum is broken off and usually it is so rotated that the fractured surface faces outward, and satisfactory reduction by closed manipulation cannot be accomplished, consequently, open reduction is indicated.

Fig 10-4 Fracture of internal epicondyle of the humerus after open reduction and fixation with a projecting wire which was removed after union was firm.

The patient is placed supine on an ordinary fracture table with the arm across the chest or abducted and pronated and supported on an arm board or side table. The extremity is so draped that it can be manipulated freely.

A longitudinal incision about 4 inches long is made over the external condyle of the humerus and carried down through the deep fascia to expose the fracture. The loose condyle is grasped with Kocher's forceps and rotated back into its normal position and held in place by direct pressure. Then one or two Kirschner wires or thin wire nails are passed through the intact skin and drilled or driven through the condyle and into the lower end of the humerous to fix the capitellum in its normal position. The wires are then cut off about 1 inch from the skin and bent at a right angle to prevent them from drifting into the tissues. The wound is closed in layers and the arm is immobilized in a plaster cast with the elbow flexed 90° and the forearm supinated. Five or six weeks later the cast and the wires are removed and the patient may begin to exercise the elbow and to use the extremity.

Supracondylar and T or Y Fractures of the Humerus. Most of the supracondylar fractures occur in children and can be treated satisfactorily by

manipulative reduction and immobilization in a plaster cast while the T or Y fractures which occur in adults can be treated by traction. However, occasionally open reduction and internal fixation are necessary. The patient lies prone on an ordinary operating table with the abducted arm supported on an arm board and the flexed forearm hanging over the end of this board. The arm is so draped that it can be manipulated freely.

A longitudinal incision is made in the posterior surface of the lower third of the arm and is carried down through the deep fascia to expose the distal half of the triceps muscle and the olecranon. The triceps tendon is split in the midline and retracted to expose the fracture. If necessary one or both halves of this tendon can be detached from the olecranon and the incision extended downward to permit retraction and more satisfactory exposure of the lower end of the humerus.

When adequate exposure is obtained the fracture can be reduced by leverage and direct pressure on the fragments and then fixed with two or more loops of stainless steel wire, Kirschner wires, slender screws or threaded wires. Y shaped metal bone plates have been used in this area, but I have not found them necessary and hesitate to leave so much metal so close to the joint. If Kirschner wires are used these can be drilled through the intact skin, then bent 90° about one-half inch from the skin and cut off.

When satisfactory internal fixation has been accomplished the triceps tendon is repaired and reattached to the olecranon if necessary and the wound is closed in layers. With the elbow flexed to 90° the limb is then immobilized in a long posterior plaster mold or a plaster cast which extends from the upper arm to the base of the fingers. The cast is left on for from six to eight weeks and then it and the Kirschner wires are removed and the arm carried in a sling and exercises are begun for the purpose of restoring movement in the elbow.

Fractures of the Olecranon. If the fragments are separated more than one-eighth inch, open reduction and fixation is necessary.

The patient is placed supine on an ordinary operating table with the forearm across the chest and so draped that it can be manipulated. The fracture is subcutaneous and is exposed by a U or a longitudinal incision. The loose fragment of the olecranon is retracted to expose the joint, and this is flushed with sulfonamide solution; loose fragments of bone and periosteal tags are removed. Then as the forearm is straightened with a sharp rake retractor and the detached fragment is pulled down held in place by a loop of stainless steel wire which is passed through a hole in the proximal portion of the ulna and through the triceps tendon or through a hole in the detached fragment. The detached fragment may be fixed to the ulna with a nail, threaded wire or long screw. In some instances a second wire loop may be necessary to maintain anatomic reduction.

The wire is twisted tight and cut off and the ends bent down against the bone and the wound is closed in layers and a plaster cast is applied with the elbow flexed 90°. This cast is left on for four or five weeks and then removed. Exercises of the elbow and use of the extremity are encouraged.

If the olecranon is comminuted it is usually advisable to remove the

smaller fragments and fix the main fragment to the shaft of the bone. Occasionally the olecranon is fractured at its base and the shaft of the bone with the radius is displaced forward. In such instances, if difficulty is encountered in maintaining reduction, a heavy steel wire or Steinmann pin may be drilled down through the olecranon and into the shaft of the ulna after anatomic reduction has been accomplished. This pin is removed after solid union of the fragments has taken place (about eight weeks) or a long wood type screw may be used and left in place.

Fractures of the Head or Neck of the Radius. *In children the neck of* the radius is the point of least resistance and may be fractured while in adults the neck remains intact and the head may be fractured or broken off and displaced. In either case the fracture demands open reduction if the character of the fracture and displacement are such that if union should occur with the fragments in their present position rotation of the forearm will be limited.

The patient is placed supine on an ordinary operating table with the forearm across the chest and the extremity so draped that the forearm can be manipulated freely. The head of the radius is exposed by an incision which begins over the external epicondyle of the humerus and extends downward and backward along the distal border of the anconeus to the proximal portion of the shaft of the ulna. The incision is carried down through the deep fascia and the muscles are separated and the capsule of the elbow joint is incised to expose the head of the radius. Care is taken not to injure the posterior interosseous nerve which lies in the supinator brevis muscle and winds around the proximal third of the radius just distal to the neck of this bone.

In a child the head of the radius is usually intact and the fracture involves only the neck of the bone. In such instances the head of the bone usually retains some periosteal attachments and it is carefully manipulated back into its normal position and the extremity maintained in a position in which the head is stable while the wound is closed in layers and a plaster mold or cast is applied. This is done in a child even if the head is completely detached.

In an adult the head is usually fragmented to a variable degree and may be broken off at the neck of the bone and it is necessary to remove the head in order to restore free rotation of the forearm. The muscles are retracted and the periosteum is incised around the neck while the forearm is alternately pronated and supinated. Then with a sharp thin osteotome or with sharp pointed bone cutting forceps the neck is cut through by cutting the cortex with the osteotome or the tips of the bone forceps while the forearm is rotated. When the bone is cut through the head is removed and the stump of the neck is smoothed with rongeurs and any remaining tags of periosteum are excised. No attempt is made to cover the end of the bone with soft tissue. The wound is closed in layers and the arm is immobilized in a plaster cast which extends from the upper arm to the base of the fingers. In a child in which the head of the radius has been replaced the cast is left on for from four to eight weeks. In an adult in whom the head has been removed the cast can be taken off after two or three weeks and movement of the forearm encouraged.

Fractures of the Proximal Third of the Ulna and Dislocation of the Head of the Radius (Monteggia Fracture). In this injury the shaft of the ulna is broken in its proximal portion by direct violence and the fragments and the head of the radius are displaced by the fracturing force. Usually the head of the radius is not broken and its removal is not indicated. It is necessary to reduce the dislocation of the head of the radius and the fracture of the ulna and usually this can be done by direct pressure and manipulation. An open reduction of one or of both lesions may be necessary.

The patient is placed supine on an ordinary operating table and the abducted arm is supported on a side table or fracture board and is so draped that it can be manipulated.

If the head of the radius can be reduced satisfactorily the fracture in the ulna can be exposed by a longitudinal incision over the subcutaneous surface of this bone. The fragments are then manipulated into position and are fixed by whatever method is most applicable. In oblique fractures screws or wires may be satisfactory or a long medullary pin introduced from above through the olecranon may be used. In transverse fractures the pin is preferable.

If the head of the radius cannot be reduced satisfactorily by closed manipulation an open reduction is indicated. This can be done by the incision described above which begins over the lateral epicondyle of the humerus and courses downward and outward along the distal or anterior border of the anconeus to the shaft of the ulna. If desired this incision can be extended down the shaft of the ulna and both the fracture and the dislocation can be exposed and reduced through the single incision. The fracture is then fixed internally and the wound closed in layers and the *arm immobilized in a plaster cast for eight weeks with the elbow flexed to* 90° and the forearm in the neutral position as regards rotation. At the end of this time the cast is removed and exercises begun in an effort to restore function to the extremity.

Fractures of the Shaft of the Radius Alone. Not infrequently an open reduction is necessary if this fracture is to be treated satisfactorily (Figs. 10-5, 10-6, 10-7). The patient is placed supine on an ordinary operating table with the forearm across the chest and the extremity is so draped that it can be manipulated. The arm may be abducted and supported on an arm board or side table.

The fracture is exposed through a longitudinal incision about 4 inches long which is carried down through the deep fascia and between the brachioradialis and the radial extensor muscles to the bone. The fracture is reduced by manipulation and leverage and may then be so stable that no internal fixation is necessary. If it is not quite stable it can be fixed by a loop of stainless steel wire passed through small drill holes in each fragment or by a Kirschner wire which is drilled obliquely through the cortex of the distal fragment and up through the medullary canal of each fragment. This wire is then left protruding through the skin and its end is cut off and bent 90° to prevent the wire from drifting into the tissues.

The wound is then closed in layers and the forearm is immobilized in [illegible]rsal and a short volar padded board splints. These splints are

smaller fragments and fix the main fragment to the shaft of the bone. Occasionally the olecranon is fractured at its base and the shaft of the bone with the radius is displaced forward. In such instances, if difficulty is encountered in maintaining reduction, a heavy steel wire or Steinmann pin may be drilled down through the olecranon and into the shaft of the ulna after anatomic reduction has been accomplished. This pin is removed after solid union of the fragments has taken place (about eight weeks) or a long wood type screw may be used and left in place.

Fractures of the Head or Neck of the Radius. In children the neck of the radius is the point of least resistance and may be fractured while in adults the neck remains intact and the head may be fractured or broken off and displaced. In either case the fracture demands open reduction if the character of the fracture and displacement are such that if union should occur with the fragments in their present position rotation of the forearm will be limited.

The patient is placed supine on an ordinary operating table with the forearm across the chest and the extremity so draped that the forearm can be manipulated freely. The head of the radius is exposed by an incision which begins over the external epicondyle of the humerus and extends downward and backward along the distal border of the anconeus to the proximal portion of the shaft of the ulna. The incision is carried down through the deep fascia and the muscles are separated and the capsule of the elbow joint is incised to expose the head of the radius. Care is taken not to injure the posterior interosseous nerve which lies in the supinator brevis muscle and winds around the proximal third of the radius just distal to the neck of this bone.

In a child the head of the radius is usually intact and the fracture involves only the neck of the bone. In such instances the head of the bone usually retains some periosteal attachments and it is carefully manipulated back into its normal position and the extremity maintained in a position in which the head is stable while the wound is closed in layers and a plaster mold or cast is applied. This is done in a child even if the head is completely detached.

In an adult the head is usually fragmented to a variable degree and may be broken off at the neck of the bone and it is necessary to remove the head in order to restore free rotation of the forearm. The muscles are retracted and the periosteum is incised around the neck while the forearm is alternately pronated and supinated. Then with a sharp thin osteotome or with sharp pointed bone cutting forceps the neck is cut through by cutting the cortex with the osteotome or the tips of the bone forceps while the forearm is rotated. When the bone is cut through the head is removed and the stump of the neck is smoothed with rongeurs and any remaining tags of periosteum are excised. No attempt is made to cover the end of the bone with soft tissue. The wound is closed in layers and the arm is immobilized in a plaster cast which extends from the upper arm to the base of the fingers. In a child in which the head of the radius has been replaced the cast is left on for from four to eight weeks. In an adult in whom the head has been removed the cast can be taken off after two or three weeks and movement of the forearm encouraged.

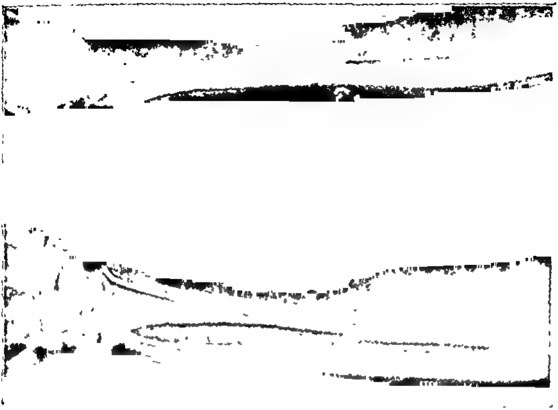

Fig. 10-6. Fracture of the middle third of the radius after open reduction and fixation with a removable intramedullary wire.

Fig. 10-7. Nonunion of the radius after open reduction and fixation with a metal plate.

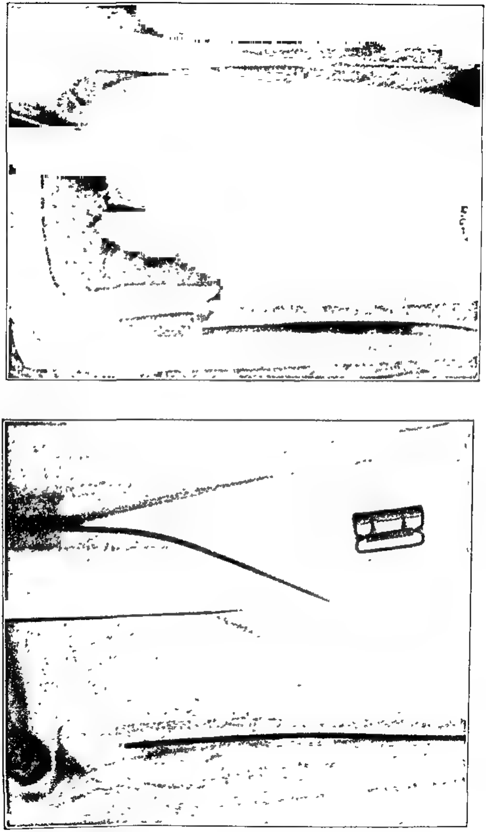

Fig. 10-5 Top, fracture in the proximal third of the radius Bottom, after open reduction and fixation with an intramedullary wire which projected through the skin

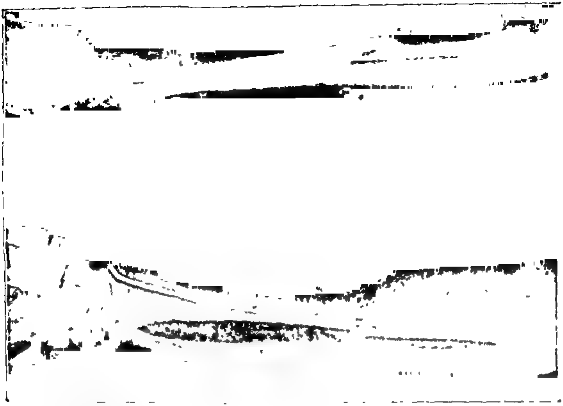

Fig. 10-6. Fracture of the middle third of the radius after open reduction and fixation with a removable intramedullary wire.

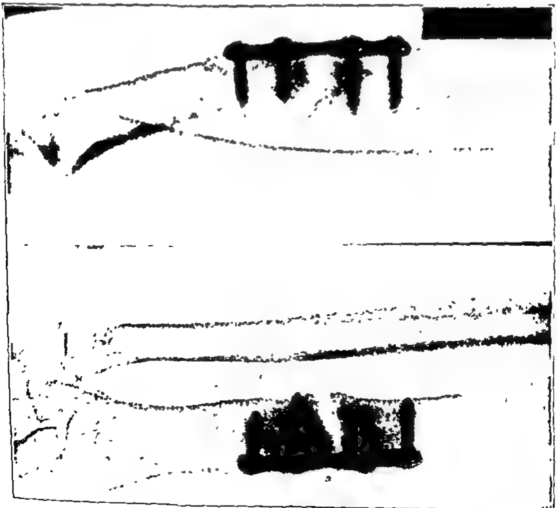

Fig. 10-7. Nonunion of the radius after open reduction and fixation with a metal plate.

applied with the forearm at 90° flexion at the elbow and in the neutral position as regards rotation. The long dorsal splint extends from the external epicondyle of the humerus to the knuckles and the volar splint is only 3 or 4 inches long. They are slightly wider than the forearm and when strapped on with adhesive the dorsal splint maintains alignment while the volar splint presses the muscles in between the bones and maintains the interosseous space.

The extremity is then immobilized in a plaster cast which extends from the middle of the arm to the base of the fingers and includes the splints. This cast is left on for from 8 to 12 weeks as the shaft of the radius is relatively slow to unite.

Fractures of the Shaft of the Ulna Alone. When open reduction of this injury is necessary, the operation and after treatment are carried out as was described in the preceding section on fractures of the shaft of the radius alone, except that the fracture is exposed by a longitudinal incision along the subcutaneous border of the ulna.

This fracture may be accompanied by dislocation of the head of the radius and if this lesion is present the dislocation should be reduced, usually by closed manipulation.

Fractures of Both Bones of the Forearm. When open reduction of this lesion is necessary the operation, internal fixation and postoperative immobilization are carried out as described in the two preceding sections on either bone alone The fractures are exposed through two separate longitudinal incisions and neither incision is closed until both bones are satisfactorily reduced and stabilized (Figs. 10-8 and 10-9).

Fracture of the Distal Fourth of the Radius (Colles). I have not operated upon a recent Colles fracture, however I have seen some excellent results obtained in severe fractures of this type by fixing the distal fragment to the ulna by two threaded stainless steel wires which slant upward and inward and are drilled through the bones while the position is maintained *by traction. Good results are also obtained by a Rush nail which is inserted* through a drill hole in the major fragment and thence into the medullary canal.

Fracture of the Carpal Scaphoid. I have not operated upon a fresh fracture of the scaphoid, but it is quite possible that the best treatment of fractures through the proximal third of this bone with a small central fragment which is doomed to avascular necrosis is excision of this fragment. In fractures of this bone with nonunion it is questionable in my mind whether a carpal fusion, a bone graft to fuse the two fragments or excision of the central fragment or of the entire bone is the operation of choice.

Dislocation of the Carpal Semilunar. In instances where closed reduction fails the displaced bone can be exposed by a straight volar incision directly over the bone and it may be forced back into place while the wrist is dorsiflexed or if it has been out so long that there is no longer a suitable bed for it the bone may be excised

Fractures of the Metacarpals. In an occasional fracture of the metacarpal, closed reduction fails and open reduction is advisable. This is especially true of the shaft of the fifth metacarpal Under local anesthesia the fracture is exposed through a dorsal incision directly over the bone and reduction is accomplished by leverage and traction. If the fracture

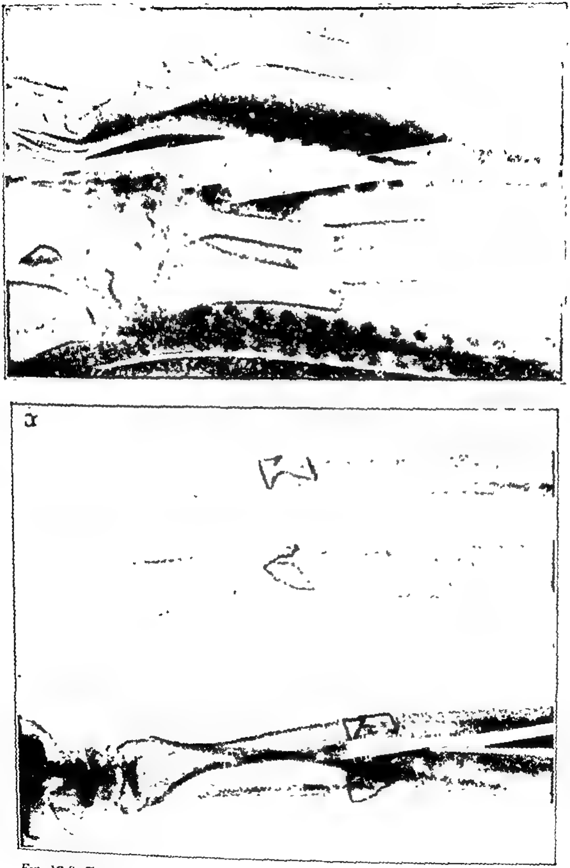

Fig 10-8 Top, fracture of both bones of the forearm Bottom, after open reduction and fixation with wire loops and plaster cast

is not quite stable the fragments are immobilized by a small Kirschner wire which is drilled obliquely through the cortex of the proximal fragment and passes down through the medullary canal or both fragments. This wire can be left protruding through the skin and can be pulled out three or four weeks later. Or a wire may be drilled transversely through each fragment and the adjacent metacarpal to fix the two bones together and thus immobilize the fracture. The hand and wrist are then immobilized in dorsal and volar plaster molds which extend from the proximal third of the forearm to the tips of the moderately flexed fingers and at the end of four weeks the wires and the plaster molds are removed and free use of the hand is permitted. At the end of one week the cast is cut back to the palmar crease to permit movement of the fingers.

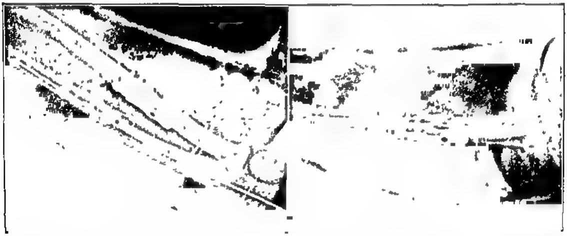

Fig. 10-9. Left, fracture of both bones of the forearm after open reduction and fixation with a plate and intramedullary wire and plaster cast. Right, anteroposterior view.

Fractures of the Phalanges. In a fracture of the shaft of a proximal or middle phalanx the joint distal to the fracture can be flexed and a small threaded or plain wire drilled through the head and up the medullary canal of the distal fragment. Then the fracture is reduced and the wire is drilled into the proximal fragment to maintain reduction. In the fracture dislocation at the proximal joint in which the anterior lip of the base of the middle phalanx is broken off and the rest of the bone is displaced backward the displacement is reduced by traction and manipulation and both interphalangeal joints are flexed and the wire is drilled through the entire length of the middle phalanx and into the proximal one in order to maintain reduction.

THE LOWER EXTREMITY

Fracture Dislocation of the Hip. More often than not it seems that a posterior dislocation of the hip is accompanied by a fracture of the rim of the acetabulum or of the head of the femur. In such instances an open reduction is indicated. The patient is placed face down on an operating table which is so broken that the hips are flexed and the thighs hang over the end of the table. The displaced head of the femur is exposed through a long oblique incision parallel to the fibers of the gluteus maximus muscle and this is carried down through the muscle, which may be extensively lacerated.

The head of the femur may slip into the acetabulum or traction and leverage may be necessary. If there is a loose fragment of the head this is removed. A large or even a quite small fragment of the rim of the acetabulum should be replaced as exactly as possible and fixed with two or more small nails or screws (Fig. 10-10). The capsule is then sutured and the limb extended by raising the end of the table and the wound is closed in layers.

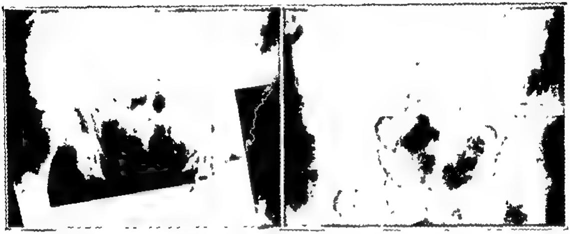

Fig. 10-10 Left, fracture dislocation of the hip. Right, after open reduction and fixation of the posterior lip of the acetabulum with two screws

The patient is then placed on a fracture table and a plaster spica cast is applied with the hip in extension and slight abduction and moderate external rotation. This is left on for from four to eight weeks.

Fractures through the Neck of the Femur. This lesion, sometimes called intracapsular fracture of the hip, is one in which operative treatment with closed or open reduction and internal fixation is the treatment of choice as this both lessens the mortality and increases the probability of union. The fragments may be fixed by a Smith-Petersen nail (Figs. 10-11

Fig. 10-11 Left, fracture of the neck of the femur after closed reduction and fixation with a Smith-Petersen nail. Right, lateral view. Union occurred, but was followed by aseptic necrosis 3½ years later

and 10-12) of the standard or of the cannulated type, or by some other form of hip nail, by multiple pins, or by one of the screws now on the market (Fig. 10-13). The surgeon should use that method which is most satisfactory in his hands and for which he has the equipment. We shall describe the closed reduction and the fixation with a cannulated Smith-Petersen nail inserted over a guide wire, the position of which has been checked by the x-ray. Either local or general anesthesia can be used.

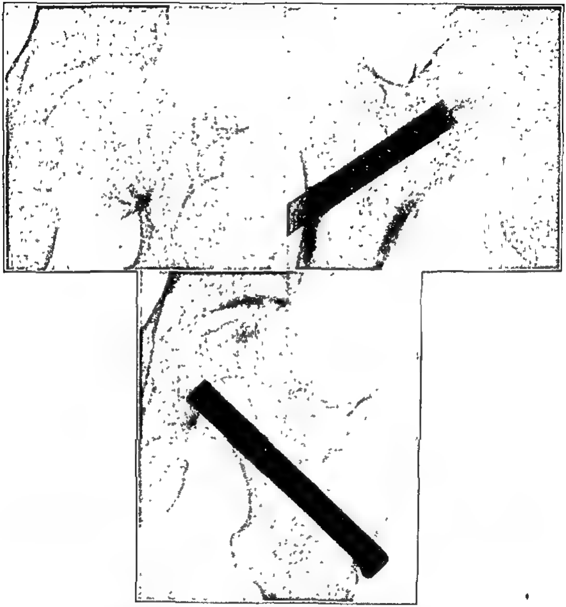

Fig. 10-12. Top left, fracture of the neck of the femur. Top right, showing a Smith-Petersen nail being inserted over a guide wire after closed reduction. Bottom, united fracture of the neck of the femur in which the nail was inserted in the lower portion of the head and neck

Reduction. The patient is placed supine on a fracture table or an ordinary operating table with a tunnel for the x-ray film holder under the hip. When satisfactory anesthesia has been obtained the fracture is reduced by the method of Leadbetter. The hip and knee are flexed to 90° and while an assistant fixes the pelvis the surgeon lifts the fractured extremity straight upward making traction in line with the shaft of the femur. The limb is then internally rotated and extended and slightly abducted.

If the reduction is satisfactory the extremity will be stable when placed in a position of 30° internal rotation, 30° abduction and full extension and can be supported in this position with the heel resting in the surgeon's hand. If the reduction is not complete the extremity will roll outward when the heel is supported in the palm and the manipulation should be repeated until a satisfactory reduction has been obtained. If the first attempt at reduction fails the limb is first rotated outward as it is lifted upward and then as it is rotated inward the upper thigh is pulled outward by an assistant while the limb is slowly abducted and then extended. This maneuver will usually accomplish a stable reduction. If the reduction is not satisfactory the manipulation should be repeated. Often all that is necessary is to abduct and internally rotate the extremity and increase the traction. Open reduction is rarely necessary.

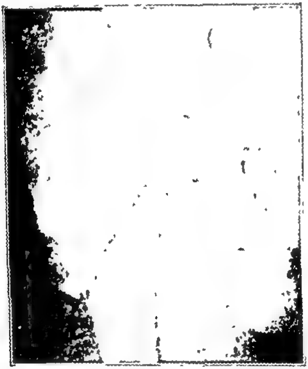

Fig. 10-13. Fracture of the neck of the femur after closed reduction and fixation with a Moriera screw.

When the reduction is satisfactory the limb should be maintained in a position of 30° abduction and 30° internal rotation and x-rays made in the anteroposterior and lateral planes. The anteroposterior film is made with the film in the tunnel under the patient and the tube directly above the hip joint and the lateral view is made with the film held above the crest of the ilium and parallel to the neck of the femur while the tube is placed between the patient's abducted legs and directed upward and outward through the hip joint. For this two portable x-ray machines are desirable and the fractured extremity should be fixed to the foot piece of the fracture table or held in internal rotation and abduction by an assistant and not moved until the operation is finished. Better lateral x-rays can be obtained by flexing the abducted hip, but the position of the fragments is liable to be lost during this maneuver.

When the x-rays have shown that the fragments are in satisfactory posi-

and 10-12) of the standard or of the cannulated type, or by some other *form of hip nail, by multiple pins, or by one of the screws now on the market* (Fig. 10-13). The surgeon should use that method which is most satisfactory in his hands and for which he has the equipment. We shall describe the closed reduction and the fixation with a cannulated Smith-Petersen nail inserted over a guide wire, the position of which has been checked by the x-ray. Either local or general anesthesia can be used.

Fig. 10-12 Top left, fracture of the neck of the femur Top right, showing a Smith-Petersen nail being inserted over a guide wire after closed reduction. Bottom, united fracture of the neck of the femur in which the nail was inserted in the lower portion of the head and neck.

Reduction. The patient is placed supine on a fracture table or an ordinary operating table with a tunnel for the x-ray film holder under the hip. When satisfactory anesthesia has been obtained the fracture is reduced by the method of Leadbetter. The hip and knee are flexed to 90° and while an assistant fixes the pelvis the surgeon lifts the fractured extremity straight upward making traction in line with the shaft of the femur. The limb is then internally rotated and extended and slightly abducted.

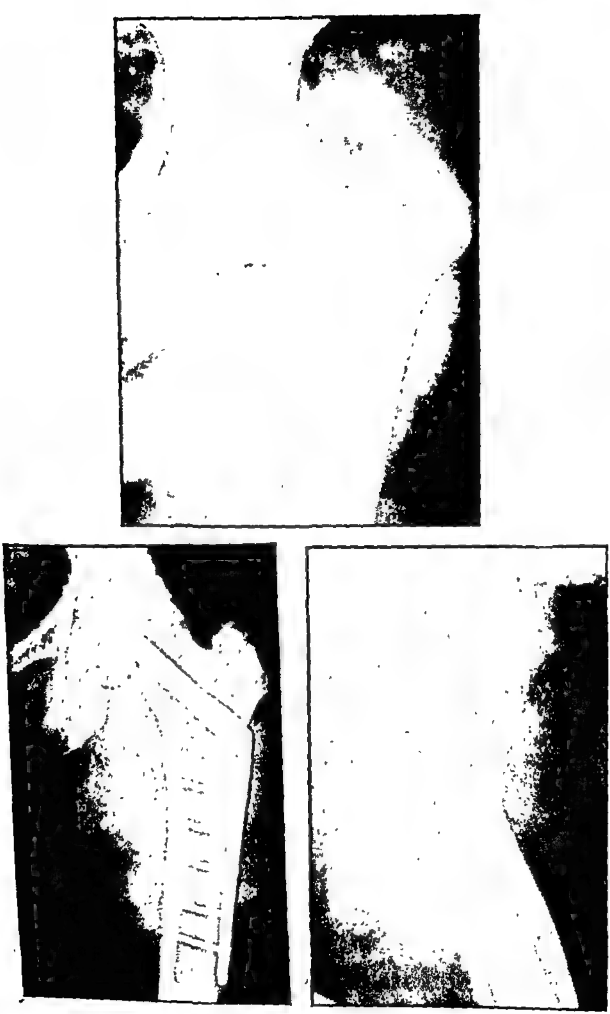

Fig. 10-14. For legend see opposite page.

tion an incision is made on the lateral surface of the femur. This incision begins at the tip of the trochanter and extends downward in line with the shaft of the femur for a distance of 5 or 6 inches. It is carried through the deep fascia to expose the base of the trochanter and the vastus lateralis muscle. The muscle and periosteum are split just below the base of the trochanter to expose the lateral surface of the shaft of the femur for a distance of about 2 inches.

At a point about 1 inch below the base of the trochanter and in the middle of the lateral surface of the shaft of the femur a guide wire $\frac{3}{32}$ of an inch in diameter and about 8 inches long is drilled through the cortex and up through the neck of the femur and into the head of the bone. This wire is drilled upward and inward at an angle of about 120° or as near as possible in line with the neck of the femur. The wire is also drilled in the horizontal plane because with the extremity rotated inward 30° the neck of the femur is approximately parallel with the floor. Another similar guide wire is drilled through the cortex and up through the neck and into the head of the bone at a point about ¼ of an inch above the first one. New x-ray films in both the anteroposterior and lateral views are made in order to check the position of the guide wires. The guide wire which is in a satisfactory position is left in place and the other one is removed. The wire not only guides the nail, but enables the surgeon to determine the length of the nail which will be most suitable for this particular fracture. If neither guide wire is in a satisfactory position one or two more are inserted and more x-rays are made until one is found to lie within the central canal of the neck and to reach approximately the center of the head of the femur. Then the other wires are removed.

A cannulated Smith-Petersen nail of such a length that it will almost reach the cortex of the head of the femur is selected and is fitted on the cannulated driver and slipped over the guide wire and driven through the lateral cortex and well into the head of the femur. The proper length of the nail is determined by measurement of the length of the guide wire in the bone and adding to this the distance from the tip of the wire to the cortex of the head of the femur. After the nail has been driven home the fragments are impacted.

Then a third series of x-rays of the hip in the anteroposterior and lateral views are made. When these show the fragments and the nail in satisfactory position the wound is closed in layers and the patient is placed in bed with a pillow under the knee. The patient may turn, sit up, or move about in bed at will and may be gotten up in a chair or on crutches as soon as the wound is sufficiently healed. The patient may use the foot to steady himself, but not bear much weight on the fractured limb until about two months after the accident. Then the crutches are discarded gradually and a cane is used until it is no longer needed.

Trochanteric and Subtrochanteric Fractures of the Femur. In the operative treatment of these fractures the ordinary Smith-Petersen nail is not

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Fig. 10-14. Trochanteric fracture of the femur before (top) and after (bottom left) fixation with a Key nail plate The lateral view (bottom right) shows an incomplete reduction, but a satisfactory result was obtained.

In order that the reduction of the fracture may be maintained until the fragments are firmly fixed by the Neufeld or other nail the patient is placed on a fracture table with a perineal post and traction foot pieces and the feet are bound to the foot pieces.

Fig. 10-17. Left, incomplete reduction and fixation of a trochanteric fracture. Right, lateral view showing deformity. The functional result was satisfactory.

Under local or general anesthesia the fractured extremity is rotated inward and pulled down until it is as long as the normal leg. Then without releasing the traction, anteroposterior and lateral x-rays are made of the hip. These should show the neck and the head of the femur as well as the proximal portion of the shaft. The anteroposterior view is made with the film in the tunnel under the hip and the lateral x-ray is made with the hip in a curved cassette in the groin or with the flat cassette held above the iliac crest and parallel to the neck while the rays are directed upward through the groin. Two portable machines placed before the operation is begun and not moved until it is finished greatly expedite the taking of the necessary films during the operation.

If the reduction is satisfactory an incision is made on the lateral surface of the thigh. This begins at the top of the trochanter and extends downward for a distance of about 8 inches. The incision is carried down to the bone, splitting the deep fascia and the proximal portion of the vastus lateralis muscle and the periosteum to expose the base of the trochanter and proximal portion of the shaft of the femur.

A hole ½ an inch in diameter is then drilled in the lateral cortex of the femur at the point ¾ of an inch below the base of the trochanter. Then a drill or heavy guide wire is passed through this hole and up through the central canal of the neck of the femur and is drilled into the head for a distance of about 1 inch.

X-rays are now made in the anteroposterior and lateral planes and if

satisfactory in many cases because it does not get a strong enough hold on the distal fragment. For this reason the Thornton plate attached to the Smith-Petersen nail; the Neufeld, Jewett or Key nail plate (Figs. 10-14 through 17); or the Moore or Blount blade plate is used. The surgeon should use the method which is most successful in his hands and for which he has the necessary equipment.

Fig. 10-15 Left, trochanteric fracture of the femur after reduction and fixation with a Neufeld nail. Right, lateral view

Fig 10-16. An unsatisfactory reduction and fixation of a trochanteric fracture of the femur. The nail was removed after union occurred and a fairly good hip obtained.

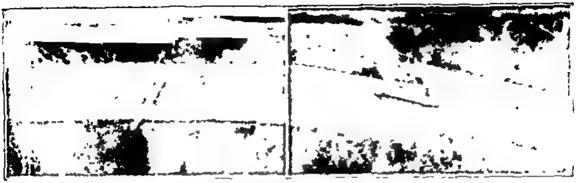


Fig. 10-20. Left, fracture of the shaft of the femur after open reduction, with the patient in bed in a splint, and fixation with a single screw. A cast was applied later. Right, antero-posterior view.

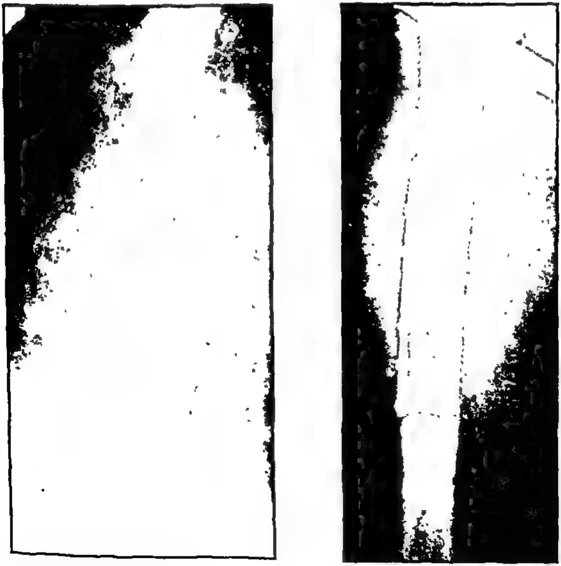


Fig. 10-21. Fracture through the shaft of the femur in traction and after internal fixation with plates in two planes. Left, a few days after the fracture. Right, postoperative film, i.e., after fixation in two planes with stainless steel plates.

these show the drill or guide wire in a satisfactory position a Neufeld or other nail plate of suitable length is selected and is fastened firmly to the driver. The length of the nail is determined by measuring the length of the drill or guide wire in the bone and the length of the plate by noting the level of the fracture. The nail should be long enough to reach almost to the cortex of the head and the plate long enough to reach well down on the shaft below the level of the fracture.

The nail is then inserted through the hole in the lateral cortex and pushed up over the guide wire and driven firmly into the head of the femur until the plate is in contact with the exposed shaft of the femur and a third series of x-rays in two planes is made in order to check the final position of the nail. If this is satisfactory the plate and the shaft are grasped with bone holding forceps and pressed together and 3 holes ($\frac{7}{64}$ of an inch in diameter) are drilled into the shaft corresponding with the holes in the plate and the plate is fastened to the shaft with the three screws which come with the plate. When the nail is inserted care is taken to so position it that the plate is in line with the shaft of the femur in order that it will lie flat against it when the nail is driven home.

The wound is then closed in layers and the patient placed in bed with a pillow under the knee. The patient may sit up, turn on the side or move about in bed freely and may be gotten up on crutches in about two weeks. However, not much weight should be borne on the extremity until the x-ray shows fairly firm union. Usually this occurs in about two months but in some instances union progresses more slowly and this is especially true of fractures through the base of the neck of the femur.

Fig 10-18 Fracture of the shaft of the femur fixed with two metal plates. Note slow union across fracture site.

Fig 10-19 Fracture of the shaft of the femur fixed with dual plates, and reinforced with iliac grafts. Operated two months after the injury

Fracture of the Shaft of the Femur. Open reduction and internal fixation of fractures of the shaft of the femur is advisable in those cases in which [illegible] by traction or manipulation [illegible] ugh 21). Where proper faciliti[illegible] rgeon) open reduction may be the method of choice even without attempting conservative treatment.

The patient is placed on a fracture table with the perineal post in position and the feet bound to the foot pieces and a moderate amount of traction is applied to both lower extremities and the fractured thigh is

early ambulation, lessens the period of hospitalization and gives results which are as good or better than those obtained by other methods.

The method is especially suitable for transverse or short oblique fractures in the middle third of the shaft of the bone. The nail may be inserted blindly under x-ray control or under direct vision at open operation. Due to difficulties encountered in effecting and maintaining reduction of the femur by the closed method we routinely use the open reduction.

Fig. 10-22 Fracture of the shaft of the femur immediately after, and four months after fixation with a medullary nail showing union with excess callus The nail is a little short and fixation may have been less than desirable, and poor fixation may stimulate excess callus.

The types of stainless steel nails in general use in this country are the Kuntscher, Street, Rush and Lottes nail. The surgeon should use the nail which works best in his hands. We prefer the Lottes' nail. This is a three-flanged nail with a heavy core which was developed in our clinic. When everything goes well, the insertion of a medullary nail into the femur may be a relatively simple procedure, but when things go wrong it may be

supported from below. Then the skin is prepared and the extremity is so draped that an adequate field is exposed.

The femur is exposed through a long vertical incision the center of which lies over the site of the fracture. This incision is placed on the posterolateral aspect of the thigh and is carried down through the deep fascia. The bleeding vessels are clamped and ligated and the vastus lateralis muscle is pulled forward and exposed as far back as possible. It is then detached from the linea aspera of the femur by sharp dissection or a periosteal elevator and is reflected forward to expose the bone. In this way the shaft of the femur can be exposed from the trochanter to the knee, if necessary, without dividing any important structures. The length of the incision varies with the thickness of the muscles, but it is made long enough to afford adequate exposure of both fragments.

When the vastus lateralis muscle is retracted forward to expose the fracture, the blood clot is removed and the fragments are grasped with bone holding forceps and manipulated into satisfactory position while the length is controlled by traction exerted by the foot piece of the fracture table. When anatomic reduction has been obtained the fragments are grasped with heavy bone holding forceps or a bone clamp and immobilized until some form of internal fixation can be applied.

The type of internal fixation used varies with the type of fracture and with the choice of the surgeon. A long oblique fracture is simply and effectively fixed by two or more metal screws which transfix both fragments and hold them together. Short oblique or transverse fractures are usually fixed with one or preferably two metal plates each of which is fixed to the bone by three or more screws. The dual plates are ideal but they are very difficult to apply. A new type of bone plate, the coaptation splint of Eggers, is a very satisfactory method of internally fixing any fracture of the shaft of a large long bone as it permits the fragments to slide together and maintains apposition.

When the internal fixation is satisfactory the vastus lateralis muscle is fastened back in position with a few mattress sutures and the deep and superficial fascia and skin are closed in layers and the limb is then immobilized either in a large plaster of paris spica cast or in a splint with traction. If the cast is used it is applied without releasing the traction or moving the limb until the main part of the plaster has set. If a splint is used either skeletal or adhesive traction may be used as relatively little weight is necessary because the object is only to immobilize the limb. A Thomas or a Bohler-Brown splint is satisfactory. The immobilization is continued as long as necessary (4 to 12 weeks depending upon the adequacy of the internal fixation and the rapidity with which union progresses).

In supracondylar fractures the distal fragment may be too short to accommodate the plates and one or two loops of stainless steel wire may be used and in such instances the external fixation must be continued longer than when more efficient internal fixation has been used.

Medullary Nail Fixation of Fractures of the Shaft of the Femur. During late years open reduction and fixation with a long intramedullary nail has become an increasingly popular method of treatment for fractures of the shaft of the femur (Fig. 10-22) This is because the method permits

proximal fragment until the driver almost reaches the tip of the trochanter. Then x-rays in two planes are made of the knee in order to determine position of the tip of the nail and the nail is then driven down to within ½ inch of the articular surface or until the driver impinges upon the trochanter. The fragments are now impacted by pounding on the flexed knee with the hand and the limb is tested for stability in rotation If it is not quite stable a metal plate is fixed across the fracture line with four short screws. Bone grafts from the ilium may be placed across the fracture line in an effort to stimulate union. The wound is closed in layers and usually no external fixation is necessary. If there are no contraindications the patient may be gotten up in a chair or on crutches within a few days after the operation. Full weight bearing is not permitted until roentgenologic and clinical examination indicate solid bony union.

The knee usually swells after the operation, but this subsides spontaneously in a few days. Unless there is some complaint it is probable that the nail need not be removed. It should not be removed until six months or more after insertion We advise removal of the nail after union is firm.

Fractures of the Distal End of the Femur. Most fractures involving the distal end of the femur are comminuted T fractures which consist of a supracondylar fracture and a vertical separation of the condyles. These are best treated by skeletal traction with a wire through the proximal portion of the tibia and the knee moderately flexed. Occasionally, however, open reduction and internal fixation is resorted to (Figs. 10-23 through 27). In such a case the fracture is exposed through a lateral incision and the condyles first fixed together with a long wood screw and then joined to the shaft with loops of wire or short plates. An additional mesial incision may be advisable in order to facilitate anatomic reduction and fixation.

In simple supracondylar fractures and in fractures of the distal end of the femur the fragments can be fixed by a Blount or Moore blade plate which is so bent that when the blade is driven through the condyles of the femur the plate will lie against the shaft. The lower third of the femur is then exposed from the lateral side and the condyles reduced if they are separated and the plate is driven through the lateral and into the mesial condyle thus firmly anchoring the plate and holding the fragments together. The fracture is then reduced and the plate is fixed to the distal portion of the shaft with screws. The limb may then be immobilized in a splint or in a cylinder cast and the patient gotten up on crutches. The cast can be removed in six weeks and the crutches discarded as soon as union is firm enough to permit full weight bearing.

Fracture of a Single Condyle of the Femur. This is a rare injury which calls for an anatomic reduction if a good functioning knee is to be obtained. Consequently, open reduction and internal fixation are indicated if the fragment is displaced and the surgeon should not hesitate to open the knee joint in order to obtain a satisfactory reduction

The fracture is exposed through a lateral or mesial incision over the displaced condyle and the large loose fragment is pried or pushed back in place and fixed to the other condyle and shaft with metal screws or with two or more Kirschner wires which are left projecting through the skin so that they can be removed after union is sufficiently solid.

very difficult for the surgeon and dangerous for the patient. Consequently, the operation should not be attempted by anyone except a surgeon who has had adequate training and experience in bone surgery. Furthermore, he should have the proper special equipment on hand and the correct length and diameter of nail for this particular femur should be selected before the operation is started.

The length of the nail to be used is determined by measuring the length of the opposite normal femur from the top of the trochanter to the level of the knee joint. This will permit the point of the nail to reach within ½ inch of the articular surface of the condyle while the threaded portion of the nail projects above the trochanter. The length of the femur can be determined more accurately by taking anteroposterior x-rays of the knee and hip with a Kirschner wire laid across the cassette and under each joint. The distance between the wires is measured and also the distance from the image of each wire to the corresponding end of the bone and the three are added to give the length of the femur. A nail ½ inch shorter than the femur is used.

The diameter of the nail is even more important than the length because if it is too small, fixation will be inadequate and this may lead to delayed or nonunion; if it is too large the nail may split the shaft or get stuck in the canal and be very difficult to remove. The narrowest part of the canal is at the junction of the middle and upper thirds of the femur. The width of the medullary canal in this area is measured on the x-ray film of the original fracture or a new x-ray film of this area is taken if necessary. A nail with a diameter $\frac{3}{64}$ inches less than that of the canal is the correct size to use.

Insertion of the Nail. The patient is placed upon a regular operating table and turned on his sound side, and the sound limb is strapped to the table. The hip and knee of the fractured limb are moderately flexed and so draped that both the region above the trochanter and the lateral surface of the thigh are exposed and the limb can be manipulated freely.

The fracture is exposed through a posterolateral incision as described in the preceding section and the distal end of the proximal fragment is lifted from the wound, adducting the distal fragment if necessary. Then the guide wire is driven or pushed up the medullary canal and out through the top of the trochanter until its tip is palpable under the skin. The skin is incised to admit a finger and the guide wire drawn back with its tip just palpable above the top. Then the tip is palpated in order to determine whether or not it has emerged in the right area. In fractures of the proximal third it is desirable that the wire emerge through the superior surface of the neck just mesial to the trochanter in order to prevent abduction of the short proximal fragment. In others it should emerge through the top of the trochanter.

Having ascertained that the guide pin is in the proper place it is then pushed up until it projects from the wound and the tip is removed and the nail is screwed on. The driver is then attached and the nail is driven down until it projects about ½ inch from the end of the proximal fragment The guide wire is removed and the fracture is reduced anatomically by slipping the distal fragment over the nail and carefully correcting the position in rotation and alignment, and the nail is driven down into the

Postoperatively the extremity should be immobilized in a splint with traction or in a spica plaster cast just as in fractures of the shaft of the femur. If firm fixation is obtained a cylinder cast may be used.

Fig. 10-24. Left, comminuted supracondylar fracture of the femur after open reduction, with the patient in bed in a splint, and fixation with two screws. A cast was applied later. Right, lateral view. Muscle interposition had prevented reduction in this and in Figure 10-20.

Fig. 10-25. Left, supracondylar fracture of the femur with separation of the condyles and comminution. Middle and right, same after fixation with a blade plate. The reduction is not perfect, but a satisfactory result was obtained.

Fractures of the Patella. In most instances this bone is broken by indirect violence and not only is the patella broken but the quadriceps aponeurosis on either side to torn to a variable degree and the proximal fragment is pulled upward by the quadriceps muscle. When the separation is one-eighth of an inch or more, open reduction and internal fixation

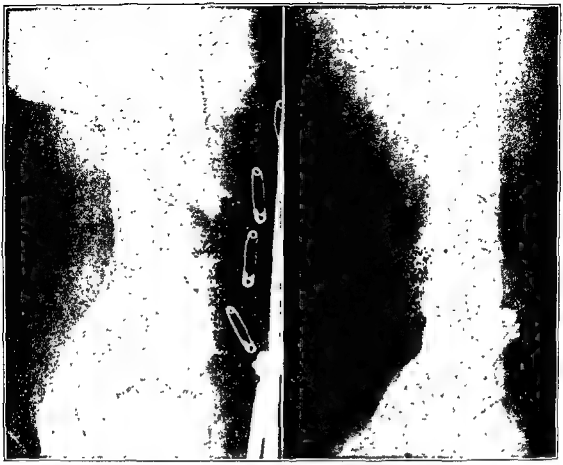


Fig. 10-23 Top left, comminuted fracture of the distal third of the femur. Top right, after open reduction and fixation with wire loops and a Thomas splint. A cast was applied later Bottom, lateral view.

by splitting the patella vertically and dissecting the bone fragments from without inward.

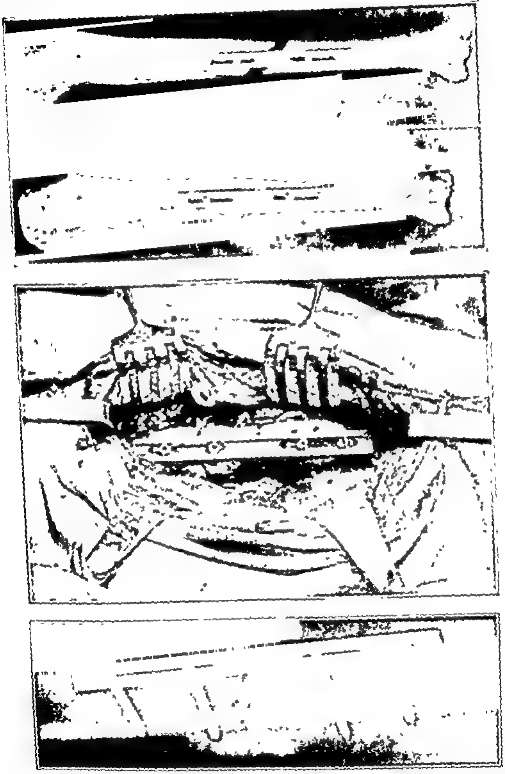


Fig 10-27 Top, the Eggers contact splint showing longitudinal motion permitted Middle, the splint applied to femur after open reduction Bottom, the splint after union had occurred (Courtesy Dr. G W. N Eggers and J Bone & Joint Surg., 30 40, 1948)

After one of the above procedures has been done the torn aponeurosis on either side is sutured with interrupted mattress sutures of silk or chromic catgut. When the patella is excised we overlap the margins of the aponeurosis, thus creating a firm quadriceps tendon across the defect. Then

or excision of one or both fragments is advisable if a satisfactory knee is to be obtained.

In the past all of the bone except completely detached fragments was saved, but during recent years Thompson's method of excising the smaller fragments and suturing the quadriceps tendon or the patellar ligament to the large fragment has been widely practiced. Also there is a growing tendency toward complete excision of the bone especially in severe comminuted fractures.

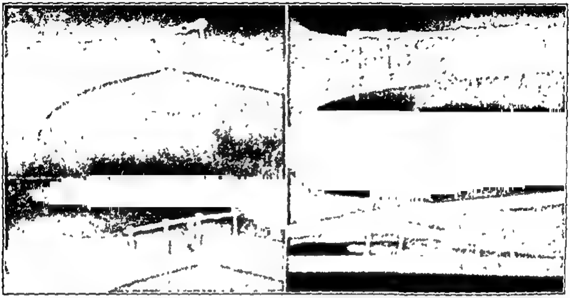


Fig 10-26 Left, failure of a plate to hold a fracture of the femur. Right, after fixation with a plate and an onlay autogenous bone graft.

The fracture is exposed through a long vertical or a short U-shaped incision. I prefer the U-shaped incision with the bottom of the U over the patellar ligament as this does not place the skin incision directly over the fracture. The incision is carried down to the aponeurosis and the patellar ligament and the flap of skin and subcutaneous tissue is retracted upward to expose the fracture. The blood clot and loose fragments are then removed from between the fragments and from the knee joint. The wound is inspected and a decision as to the operative procedure is made. If there are two fairly large fragments these are reduced anatomically and fastened together with a loop of fairly heavy stainless steel wire which usually passes transversely through the larger fragment and around the smaller one. As the wire is first pulled and then twisted tightly, care is taken that the reduction is as near anatomic as possible in order that the articular surface of the patellar may be relatively smooth.

If one fragment is relatively small or comminuted or both this is excised and the tendon or ligament is fastened to the large fragment with sutures of heavy silk or linen or chromic catgut. In order to accomplish this two vertical holes are drilled through the bone and the sutures are first woven through the tendon or ligaments. The ends are passed through the holes in the large fragment and tied over the end of the bone.

If the bone is extensively comminuted the entire bone is excised, care being taken to preserve the aponeurosis over the bone. This is best done

in order to get under the depressed area. An attempt is made to restore the normal contour of the articular surface and the loose fragments are held up by bone chips or grafts cut from the tibia below the fracture.

If there is a large lateral fragment this is fastened with two or more Kirschner wires which are left projecting through the skin and are removed about six weeks later.

As a rule, little attention is paid to the fracture of the proximal end of the fibula which usually accompanies this injury. When the articular surface of the tibia is restored as well as it can be done and the loose fragments are propped up in position and fixed, the wound is closed in layers.

The original cast or a new one like it, but without the window remains on for eight weeks. Then it is removed and exercise of the knee without weight bearing is begun. Weight bearing is not permitted until it is believed that the surface of the condyle is strong enough to stand it (three months or more).

Fractures of the Internal Condyle of the Tibia. In these fractures with displacement the treatment is similar to that described in preceding paragraphs except that the leg is immobilized in abduction and the window in the cast and incision are on the inner side of the extremity.

T or Y Fractures of the Proximal End of the Tibia. Usually these can be treated satisfactorily by traction, but occasionally open reduction and internal fixation is indicated.

The fracture is exposed by a long anterolateral incision and the anterior tibial muscle is retracted or reflected to expose the fracture. First the two condyles of the tibia are reduced anatomically and fastened together with one or more long metal screws, wires or bolts. Then the distal shaft fragment is reduced and fastened to the lateral condyle with a metal plate and screws if the fracture is transverse or with two or more screws if the contour of the fragments permits screw fixation. The wound is then closed in layers and the extremity is immobilized in a long cylinder cast with the knee in a position of slight flexion or in a splint with traction. Immobilization is continued for 8 to 12 weeks or until union is quite firm Then exercises and gradual resumption of weight bearing are prescribed.

Fractures of the Shaft of the Tibia Alone. In fractures of the shaft of the tibia alone the intact fibula maintains the length of the extremity and it is very unusual to encounter a displacement of the fragments of the tibia which requires an open reduction. Occasionally, however, the fragments are displaced and so locked that a satisfactory position cannot be obtained by manipulation.

In such a case the fracture can be exposed by a longitudinal incision about 3 inches long which is placed lateral to the crest and over the anterior tibial muscle or tendon Then an instrument (blunt dissector or periosteal elevator) is introduced between the fragments and the displacement is corrected by direct leverage. If necessary anatomic reduction can be maintained by a screw or by a Kirschner wire or threaded wire introduced through the skin, but as a rule the fragments are quite stable and internal fixation is not necessary.

The wound is then closed in layers and the extremity is immobilized in a plaster cast which extends from the midthigh to the toes and is applied with the knee slightly flexed and the foot dorsiflexed to about 90°. The

the superficial fascia and skin are closed in layers and the knee is immobilized in extension in a plaster of paris cast.

The immobilization is continued for from two to eight weeks or more depending upon the security of the internal fixation and the reliability of the patient. It is to be remembered that the patella may undergo extensive atrophy and it may be necessary to guard the knee from excessive strain for several months after the operation.

Fractures of the Spine of the Tibia. In this unusual injury the tibial spine is broken and pulled off with the anterior crucial ligament. Consequently, unless it is operated upon an unstable and eventually an arthritic knee may be expected.

The knee is opened by an incision mesial to the patellar ligament which extends down below the tibial tubercle. This is carried down through the aponeurosis and the lateral portion of the fat pad into the joint. The intercondylar space is inspected and the defect in the proximal surface of the tibia is located. Two small holes are drilled from the anterior surface of the tibia to emerge in the defect from which the spine has been avulsed. Then a piece of fine (28 or 30) stainless steel wire is passed through one of these holes, threaded on a small curved needle, passed through the crucial ligament adjacent to the fragment of bone and then the needle is removed and the end of the wire is pulled out through the second hole to emerge on the front of the tibia. The wire is pulled taut and the fragment of bone is carefully guided into its original position and the wire is twisted tight enough to hold it in place. The wound is then closed in layers and the knee is immobilized in a plaster cast in a position of full extension for from six to eight weeks.

Fracture of the External Condyle of the Tibia. If there is a large loose fragment or if the surface of the condyle is depressed to such a degree that the mechanics of the knee joint are altered and a genu varum may be expected an attempt should be made to reduce the deformity and restore the articular surface by open operation as it has been my experience that this cannot be done by manipulation and compression. However, with more experience I am inclined to operate upon these cases less often.

Before the operation the leg is adducted strongly on the thigh and immobilized in this position in a long plaster cast which extends from the groin to the toes. Then a large window is cut in the cast over the lateral side of the knee and proximal half of the leg and the operation is performed through this window This method is used because of the danger of reproducing the deformity if the surgeon applies the cast after the operation.

The fracture is exposed through a long lateral incision which begins over the condyle of the femur and extends down to the junction of the middle and upper thirds of the leg. This is carried down to the bone opening the knee joint and reflecting part of the origin of the anterior tibial muscle. Then the large cortical fragment is retracted and the joint surface is inspected. If the external semilunar cartilage is badly damaged, and especially if it lies between the fragments it is removed.

It will usually be found that the central portion of the articular surface of the condyle is depressed and extensively comminuted. This is pushed upward and if necessary a window is cut in the lateral side of the tibia

in order to get under the depressed area. An attempt is made to restore the normal contour of the articular surface and the loose fragments are held up by bone chips or grafts cut from the tibia below the fracture.

If there is a large lateral fragment this is fastened with two or more Kirschner wires which are left projecting through the skin and are removed about six weeks later.

As a rule, little attention is paid to the fracture of the proximal end of the fibula which usually accompanies this injury. When the articular surface of the tibia is restored as well as it can be done and the loose fragments are propped up in position and fixed, the wound is closed in layers.

The original cast or a new one like it, but without the window remains on for eight weeks. Then it is removed and exercise of the knee without weight bearing is begun. Weight bearing is not permitted until it is believed that the surface of the condyle is strong enough to stand it (three months or more).

Fractures of the Internal Condyle of the Tibia. In these fractures with displacement the treatment is similar to that described in preceding paragraphs except that the leg is immobilized in abduction and the window in the cast and incision are on the inner side of the extremity.

T or Y Fractures of the Proximal End of the Tibia. Usually these can be treated satisfactorily by traction, but occasionally open reduction and internal fixation is indicated.

The fracture is exposed by a long anterolateral incision and the anterior tibial muscle is retracted or reflected to expose the fracture. First the two condyles of the tibia are reduced anatomically and fastened together with one or more long metal screws, wires or bolts. Then the distal shaft fragment is reduced and fastened to the lateral condyle with a metal plate and screws if the fracture is transverse or with two or more screws if the contour of the fragments permits screw fixation. The wound is then closed in layers and the extremity is immobilized in a long cylinder cast with the knee in a position of slight flexion or in a splint with traction. Immobilization is continued for 8 to 12 weeks or until union is quite firm. Then exercises and gradual resumption of weight bearing are prescribed.

Fractures of the Shaft of the Tibia Alone. In fractures of the shaft of the tibia alone the intact fibula maintains the length of the extremity and it is very unusual to encounter a displacement of the fragments of the tibia which requires an open reduction. Occasionally, however, the fragments are displaced and so locked that a satisfactory position cannot be obtained by manipulation.

In such a case the fracture can be exposed by a longitudinal incision about 3 inches long which is placed lateral to the crest and over the anterior tibial muscle or tendon. Then an instrument (blunt dissector or periosteal elevator) is introduced between the fragments and the displacement is corrected by direct leverage. If necessary anatomic reduction can be maintained by a screw or by a Kirschner wire or threaded wire introduced through the skin, but as a rule the fragments are quite stable and internal fixation is not necessary.

The wound is then closed in layers and the extremity is immobilized in a plaster cast which extends from the midthigh to the toes and is applied with the knee slightly flexed and the foot dorsiflexed to about 90°. The

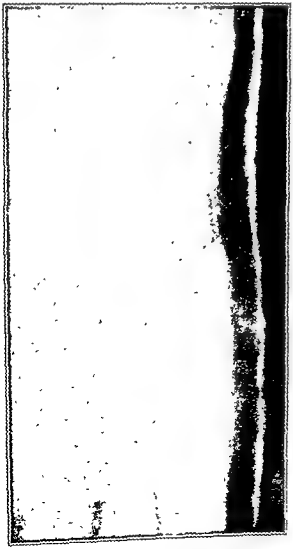


Fig 10-28. Top left, comminuted fracture of proximal third of both bones of the leg. Top right, after reduction and fixation with two screws and cast. Bottom, lateral view

cast is left on until the union is firm (about 10 weeks in an adult). The cast is removed and weight bearing is resumed gradually. The swelling is controlled with an elastic bandage.

Fractures of Both Bones of the Leg. These are relatively frequent fractures which may result from either direct or indirect violence and may require expert treatment if union in satisfactory position is to be obtained. Not only are these fractures often compound on account of the subcutaneous position of the tibia, but this bone may be extensively comminuted and position of the fragments may be difficult to maintain without traction or external skeletal fixation even after a satisfactory reduction.

In simple fractures of both bones of the leg in which open reduction is decided upon the treatment is directed at the tibia and usually the fibula is more or less ignored as it is found that if the fragments of the tibia are reduced and maintained in a satisfactory position, those of the fibula will follow the fragments of the larger bone and will unite without difficulty. In preparing the leg for an open reduction of a fracture of both bones of the leg the patient may be placed on a fracture table with the foot fixed to the foot piece and the knee supported. The leg is immobilized and the shortening corrected by traction. The fracture is exposed and the fragments are reduced while the traction is maintained.

However, a fracture table is not necessary as the leg can be supported on sandbags on an ordinary table and manual traction applied to the foot after the fracture is exposed. This is accomplished by an incision 3 or 4 inches long placed lateral to the crest of the tibia and over the anterior tibial muscle. Then by leverage, manipulation and traction the displacement is reduced and whatever type of internal fixation is preferred is applied (Figs. 10-28 through 33).

Fig 10-29 Left, compound fracture of both bones of the leg after débridement, open reduction and fixation of the tibia with one screw and of the fibula with a plate The fibula was exposed through a *separate* incision Wounds closed without drainage and pressure dressing and cast applied. Right, lateral view.

Fig 10-30. Left, compound fracture (similar to Fig 10-29) in which a plate was applied to the fibula and a wire loop to the tibia. Right, anteroposterior view.

Fig. 10-31. Left, fracture of both bones of the leg Right, after open reduction and fixation of the tibia with a metal plate and plaster cast

If the fracture line is oblique the fragments are clamped together with bone holding forceps and are fixed by one or two noncorrosive screws (Figs. 10-34 through 37), or Kirschner wires or threaded wires. In transverse fractures a small wire loop or a plate or Egger's contact splint may be used. It is well to place the plate on the lateral surface of the tibia as it is unwise to place a plate on the subcutaneous surface of this bone if this can be avoided.

Fig 10-32. Fracture of both bones of the leg in which closed reduction failed.

If there is a double fracture of the tibia it may be necessary to expose and fix both fractures. A large central triangular loose fragment is sometimes present and this can be fixed to the proximal and distal fragments by screws or spanned by a long metal bone plate. Occasionally, it is well to expose the fibula by a lateral incision over the intermuscular septum. The fragments are then reduced and fixed by screws, encircling wires or a plate as indicated and the wound is closed in layers while the alignment of the leg is maintained. In certain instances the fracture of the tibia is not exposed and satisfactory reduction and fixation of the fibula is deemed sufficient for the treatment of both fractures.

The extremity is then encased in a plaster cast which extends from the midthigh to the toes and is applied over a thin layer of padding. The cast is applied with the knee in a position of slight flexion with the foot

dorsiflexed to 90°. The external fixation is continued until union is quite firm (10 to 12 weeks in an adult). Then the cast is removed and weight bearing is resumed gradually. Swelling is controlled with an elastic bandage.

Medullary Nail Fixation of Fractures of the Shaft of the Tibia. With the curved three flanged Lottes' nail this method has been used extensively in our clinic and in skilled hands is the method of choice for the internal fixation of transverse, short oblique, double or mildly comminuted fractures

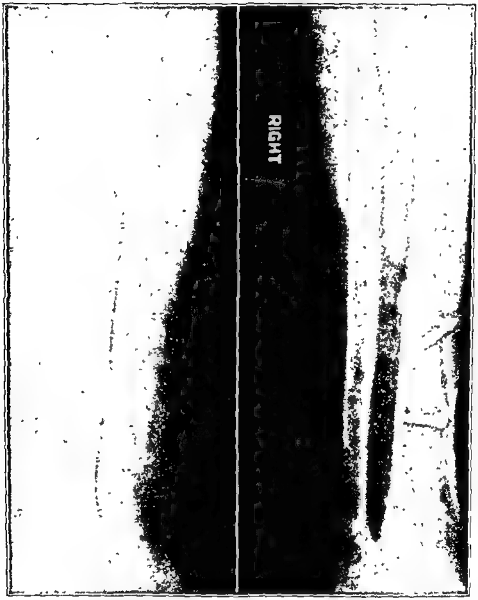


Fig. 10-33 Same as Figure 10-32 after open reduction and fixation with three screws and a cast

in the middle third of the shaft (Figs. 10-38 through 41). Due to the fact that the bone is subcutaneous the fracture can be reduced by the closed method and the nail introduced through a small incision over the proximal portion of the bone. The technic is as follows:

The patient is placed on a fracture table which is so equipped that the knee can be supported with the hip and knee flexed. The foot is fastened to the foot traction apparatus and the hip flexed and the lower thigh supported by a sling from an overhead frame or bar, or by a rest from beneath

so that the knee is flexed 90°. The fracture is reduced by traction on the foot, the knee support affording counter traction. Reduction is accomplished by strong traction and manipulation. When this appears to be satisfactory,

Fig 10-34. Old fracture of the leg united after fixation with dual plates and the application of iliac grafts

the skin is prepared and the leg is draped and an incision about 2 inches long is made on the anteromesial surface of the leg about ½ inch mesial to the tibial tubercle, care being taken not to enter the knee joint. The lower part of this incision is carried down to the bone and the periosteum is

reflected over a small area directly mesial to the tibial tubercle. A hole $\frac{3}{8}$ inch in diameter is drilled through the cortex in the anteromesial surface of the tibia opposite the middle of the tibial tubercle. The drill is started at right angles to the cortex and then is directed downward and backward as obliquely as possible, the skin at the upper part of the incision being protected with a thin metal plate.

Fig. 10-35 Comminuted fracture of the leg after open reduction and fixation with one screw and a cast. The fibula united satisfactorily.

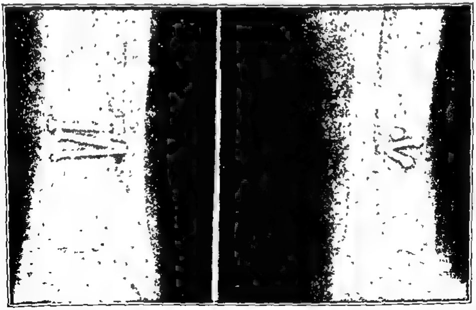


Fig. 10-36 Comminuted fracture of the tibia after open reduction and fixation with three screws. The fibula was broken at a higher level.

The tip of the nail is inserted into the drill hole with the convex surface resting on the bone and the flange on the concave surface directed towards the crest of the tibia. The driver is depressed so that the nail enters the bone

as obliquely as possible and it is driven down the medullary canal of the proximal fragment until it reaches the site of the fracture. The proper distance can be determined by measuring the distance from the tibial tubercle to the fracture on the x-ray film with a tibial nail of the same length as the one being used.

At this point the fracture is checked carefully by palpation and manipulated if necessary in order to be sure that the reduction is satisfactory. Likewise, the position of the foot in rotation is inspected and corrected if this is not satisfactory. The nail is then driven down past the fracture for a distance of 2 or 3 inches and the traction is lessened but not released completely and the stability of the fragments is tested. If the nail has penetrated the distal fragment the fracture should be quite stable.

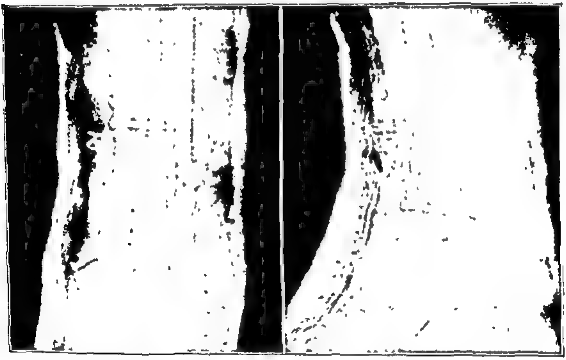


Fig. 10-37. Left, comminuted fracture of the leg after open reduction and fixation of the tibia with multiple screws. Right, lateral view. A fairly good ankle was obtained.

If the fracture is not stable the nail has probably failed to enter the distal fragment. The traction should be tightened, the nail driven back to the point where its tip just fails to reach the fracture and the reduction repeated and the nail driven down again. In fractures in the proximal third of the bone it is well to deliberately displace the distal fragment backward a short distance, as here the tip of the nail slips along the posterior wall of the canal as it is being inserted and tends to emerge at the fracture site and pass posterior to the distal fragment. When in doubt as to the accuracy of the reduction or the position of the nail, the fracture should be checked with the x-ray in two planes. Rarely have we found it necessary to expose the fracture of the tibia in order to effect a satisfactory reduction and introduce the nail into the distal fragment.

After the fracture is stable the nail is driven down until about 1 inch

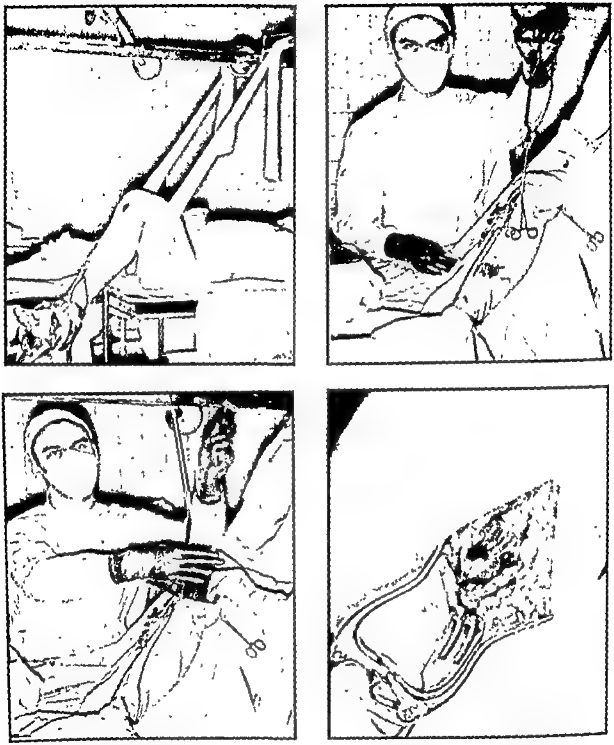


Fig. 10-38. Top left, position of the patient Note flexion of knee and overhead traction A compound fracture nailed upon admission The tibial tubercle and the line of incision have been painted on the leg to show their relationship.

Top right, the hole for the nail has been drilled in the proximal fragment and the drill is still in place.

Bottom left, illustrates the method of depressing the nail when it is first being inserted to prevent the tip from penetrating the posterior cortex It is important to depress the nail in its midportion and not attempt to depress it with the driver as the latter puts a reverse bend in the nail.

Bottom right, shows the incision and only the threaded portion of the nail protruding from the cortex after the nail has been driven home (Courtesy Dr J. O. Lottes and South. M. J., 45:407, 1952.)

protrudes from the hole in the tibia. Then x-rays in two planes are made of the ankle and if it can be done without its tip entering the joint, the nail is driven down until the driver impinges upon the cortex of the tibia.

The wound is closed in layers, the traction is released and the fracture gently impacted by pounding on the heel. The leg is now immobilized in a plaster cast which extends from the groin to the toes. It is applied with the knee in extension and the foot dorsiflexed. The patient may be up on crutches within a day or so and active straight leg exercises in hip flexion and extension are encouraged. In two weeks the cast and sutures are removed and a new cast applied. In short oblique or transverse fractures this is fitted with a walking heel and weight bearing is begun as soon as the patient is able to do so.

Fig. 10-39 Fracture of the shaft of the tibia fixed with a medullary nail. The posterior bowing was corrected later by manipulation

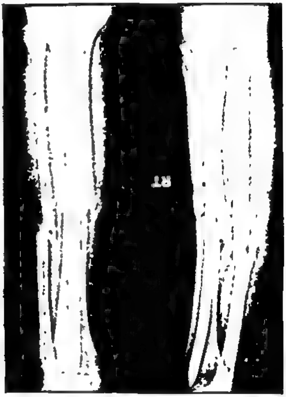
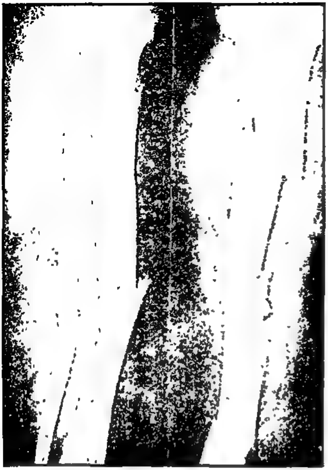


Fig. 10-40. Fracture of the shaft of the tibia with union after fixation with a medullary nail. This fracture had failed to unite after fixation with a plate.

In long oblique or comminuted fractures weight is not borne until the fracture is well united. At the end of eight weeks the cast may be removed above the knee and a short cast applied to permit knee flexion. This is removed when union is judged to be solid. We prefer to remove the nail after the strength of the bone is judged to be about normal, but we do not think that removal of an asymptomatic nail is necessary.

Fractures at the Ankle. The fractures in this area which not infrequently require open reduction are fractures of the internal malleolus and fractures of the posterior margin of the tibia. Less frequently one encounters a fracture of both malleoli with dislocation of the foot in which the fibula



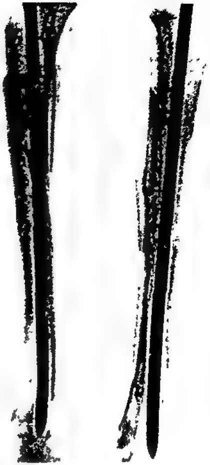


Fig 10-41. Top left, prenailing film of a compound triple segmental fracture involving all three portions of the shaft of the tibia of a 66 year old man Nailed by the closed method on admission after débridement. The patient began full weight bearing in a walking cast two months after nailing. With removal of the cast six months after nailing, he began full weight bearing without support.

Top right, seven months after nailing and one month after full weight bearing without support.

Bottom, after removal of the nail 11 months after nailing. (Courtesy Dr. J O Lottes and South. M. J., 45.407, 1952.)

is caught and locked behind the tibia or a diastasis at the ankle which requires an open operation (Fig. 10-42).

Fig 10-42 Top, a trimalleolar fracture of the ankle with diastasis. Bottom, after open reduction and fixation of the internal malleolus with one screw and of the diastasis with another screw. The small posterior fragment was ignored

Fractures of the Internal Malleolus. In severe abduction fractures the lower portion of the fibula or external malleolus is fractured and the tip of the internal malleolus is avulsed and displaced downward and forward. When the deformity is reduced and the foot is strongly inverted and dorsiflexed, if the fragment of the internal malleolus is not in satisfactory position, it should be exposed by open operation and fixed with a screw or threaded wire or Kirschner wire (Fig. 10-43).

The fracture is exposed by an incision about 3 inches long which extends downward along the anterior border of the malleolus. The small

detached fragment is exposed by retracting the posterior margin of the incision and is pulled up and held in position with a sharp retractor. Then it can be fixed by a small noncorrosive screw or nail which is directed upward and outward. If the surgeon prefers, a Kirschner wire or a threaded wire may be introduced through the intact skin and drilled through the detached fragment and up into the tibia. This is bent or cut off about ½ inch from the surface of the skin and the wound is closed in layers.

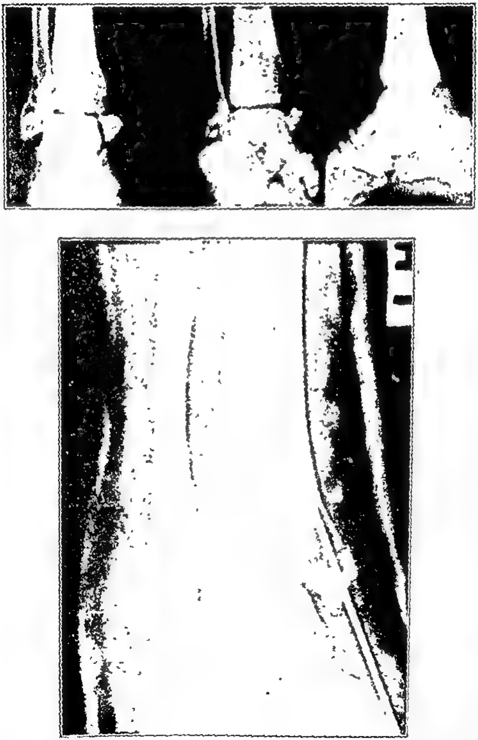


Fig 10-43 Top, a bimalleolar fracture showing the view of the internal malleolus obtained in the oblique exposure. Bottom, after open reduction of the internal malleolus and fixation with a wire which projected through the skin and was removed after union was firm.

The foot and ankle are then immobilized in a plaster cast which extends from the middle of the thigh to the toes. The cast is applied over a thin layer of sheet cotton with the knee slightly flexed and the foot slightly inverted and dorsiflexed to 90°. The cast is left on for six weeks and then it is removed and if a threaded wire or Kirschner wire has been used, this is removed. An elastic bandage is applied to the foot and ankle and weight bearing is resumed gradually.

Fractures of the Posterior Margin of the Tibia. This is usually one feature of a trimalleolar fracture with posterior displacement of the foot and the fracture of the posterior margin of the tibia may be satisfactorily reduced when the deformity is corrected and the fractures of the internal and external malleoli are reduced. Even if its position is not satisfactory it may be ignored if it is small, but if it includes one-fourth or more of the distal articular surface of the tibia and is not in almost anatomic position it should be exposed by open operation, reduced and fixed in its normal position.

In order to expose the posterior margin of the tibia the patient is placed prone on the operating table with a large sandbag under the lower third of the leg. An incision about 4 inches long is made lateral and parallel to the tendon of Achilles and this is extended down through the deep fat and fascia to expose the posterior surface of the distal fourth of the tibia. The loose fragment is found in the depth of the wound and the periosteum at its proximal margin is usually intact. The fragment is pushed down and forward into its normal position and is fixed with one or two small noncorrosive nails or screws. If the surgeon prefers, a Kirschner wire or threaded wire which protrudes through the skin and can be removed later, may be used to fix the loose fragment to the tibia. It is to be remembered that the distal articular surface of the tibia is slightly concave and that the point of the wire or screw or nail tends to project into the ankle joint unless care is taken to prevent this.

When the reduction and fixation of the posterior marginal fragment are satisfactory the lateral margin of the wound is retracted to expose the fracture of the distal portion of the fibula and this is reduced and internal fixation is applied if this is advisable. If there is also a fracture of the internal malleolus with displacement of the loose fragment this is exposed through an incision below the posterior to the malleolus and the fragment is fixed as was described in the preceding section.

After the wounds are closed the foot and ankle are immobilized in a lightly padded cast which extends from the middle of the thigh to the toes. This cast is applied with the knee slightly flexed and the foot slightly inverted and dorsiflexed to 90°. This cast is left on for from six to eight weeks and then it is removed and weight bearing is begun gradually, an elastic bandage being used to control the swelling.

Fractures of the Anterior Margin of the Tibia. Occasionally, the foot is displaced forward and a relatively large fragment of the anterior margin of the distal end of the tibia is displaced upward and forward and may be rotated. This fragment is exposed by an incision about 4 inches long which is lateral to and parallel with the extensor tendons of the toes. The

loose fragment is levered or manipulated back into its normal position and fixed with a noncorrosive screw or nail, Kirschner wire or threaded wire.

The wound is then closed and the foot and ankle are immobilized in a position of slight equinus in a lightly padded cast which extends from just below the knee to the toes. If both malleoli are broken or if the foot has been markedly displaced the plaster cast extends up to the middle of the thigh. The immobilization is continued for six weeks. At the end of this time the cast is removed and function is resumed gradually, the swelling being controlled by an elastic bandage.

Fracture Dislocation at the Ankle with Posterior Locking of the Fibula. Occasionally in a fracture dislocation of the ankle with posterior displacement of the foot it will be found that a satisfactory position cannot be obtained by the usual closed manipulation. In such a case it may be noted in the x-rays that the proximal fragment of the fibula is displaced inward and backward behind the distal portion of the shaft of the tibia. It may be locked in position by the posterolateral margin of the tibia or by the distal fragment of the fibula.

The fracture of the fibula is exposed by an anterolateral incision about 4 inches long which lies anterior and parallel to the external malleolus and the center of which lies over the fracture. The incision is carried down to expose the posterolateral margin of the tibia and a strong blunt dissector is slipped back behind the tibia and in front of the proximal fragment of the fibula and the fibula is levered outward and then forward into its normal position.

The fracture dislocation of the ankle is then reduced and the fracture inspected and the stability of the reduction is tested. If internal fixation seems necessary, whatever form is indicated is applied. The wound is then immobilized in a lightly padded cast which extends from the midthigh to the toes and is applied with the knee slightly flexed and with the foot dorsiflexed to 90°. The immobilization is continued for six weeks, then the cast is removed and weight bearing is resumed gradually. The swelling is controlled by an elastic bandage or anklet.

Diastasis at the Ankle. Occasionally in fractures at the ankle the inferior tibiofibular ligaments are torn and the malleoli are separated with a broadening of the mortise. If this condition is recognized in the fresh fracture the diastasis can usually be corrected by compression of the malleoli and if a plaster cast is applied snugly over a small amount of padding with the foot in the neutral position and is firmly molded around the malleoli the ligaments will heal by the time the fracture has healed

If the diastasis is not corrected in the acute stage of the injury open reduction and internal fixation of the tibia and fibula is necessary if a stable ankle is to be obtained. The space between the malleoli is exposed by an anterolateral incision and the soft tissue which fills the space is removed with a knife and curet if necessary and the malleoli are pressed together. Then through a short lateral incision over the distal portion of the fibula a drill hole is made through the fibula and into the tibia, the hole being placed about 1 inch above the distal articular surface of the tibia. Then with a noncorrosive screw about 1½ inches long the two bones

are fastened firmly together and the mortise is reduced to its normal dimensions.

The wounds are closed in layers and a plaster cast which extends from the tibial tubercle to the toes is applied with the foot in the neutral position and dorsiflexed to 90°. Immobilization is continued for six weeks. At the end of this time the cast is removed and weight bearing is begun gradually. The swelling is controlled with an elastic bandage or anklet.

Fracture Dislocation of the Astragalus. These are severe injuries in which the body of the astragalus is broken and displaced and in which reduction by manipulation may not be satisfactory. In such instances the fracture is exposed by a long incision which follows the posterior border of the fibula and the external malleolus and extends forward on the lateral side of the foot. The external lateral ligaments are divided and the foot is inverted and if necessary the peroneal tendons are divided. The fragments of the astragalus are reduced by leverage and manipulation, and the fragments are so adjusted that an anatomic reduction is obtained.

If the relatively scanty blood supply to the body of the astragalus has been destroyed, aseptic necrosis of this fragment and prolonged disability may be expected. In such a case an immediate arthrodesis of the ankle and of the subastragaloid joints is the treatment of choice. This is performed by removing the articular cartilage from the opposing surfaces of the astragalus and the mortise and of the os calcis and then replacing the bones in their normal relationships. The wound is then closed in layers and the foot is immobilized in a position of slight equinus and slight eversion in a lightly padded cast which extends from the midthigh to the toes. The immobilization is continued for from 10 to 12 weeks or longer if necessary. In some cases astragalectomy and fusion of the tibia to the os calcis is necessary in order to secure a stable painless foot.

Fractures and Fracture-dislocations of the Tarsal and Metatarsal Bones. Occasionally in severe injuries of the foot, fractures and fracture-dislocations of the tarsal and metatarsal bones occur in which attempts at manipulative reduction are not successful In such cases the fracture or fracture-dislocation is exposed by a dorsal longitudinal incision directly over the lesion. Then by direct pressure and leverage with a heavy blunt dissector combined with manipulation of the foot, the displacement is corrected and the stability of the reduction is tested.

If the reduction is not stable, the fragments or bones which tend to slip out of position are transfixed by one or more threaded or Kirschner wires, the ends of which are left protruding through the skin in order that they can be removed after sufficient healing has occurred. The wound is closed in layers and the foot is immobilized in the neutral position in a thinly padded plaster cast which extends from the tibial tubercle to the toes. The cast is left on for six weeks and then it is removed and weight bearing is begun. The swelling is controlled with an elastic bandage.

loose fragment is levered or manipulated back into its normal position and fixed with a noncorrosive screw or nail, Kirschner wire or threaded wire.

The wound is then closed and the foot and ankle are immobilized in a position of slight equinus in a lightly padded cast which extends from just below the knee to the toes. If both malleoli are broken or if the foot has been markedly displaced the plaster cast extends up to the middle of the thigh. The immobilization is continued for six weeks. At the end of this time the cast is removed and function is resumed gradually, the swelling being controlled by an elastic bandage.

Fracture Dislocation at the Ankle with Posterior Locking of the Fibula. Occasionally in a fracture dislocation of the ankle with posterior displacement of the foot it will be found that a satisfactory position cannot be obtained by the usual closed manipulation. In such a case it may be noted in the x-rays that the proximal fragment of the fibula is displaced inward and backward behind the distal portion of the shaft of the tibia. It may be locked in position by the posterolateral margin of the tibia or by the distal fragment of the fibula.

The fracture of the fibula is exposed by an anterolateral incision about 4 inches long which lies anterior and parallel to the external malleolus and the center of which lies over the fracture. The incision is carried down to expose the posterolateral margin of the tibia and a strong blunt dissector is slipped back behind the tibia and in front of the proximal fragment of the fibula and the fibula is levered outward and then forward into its normal position.

The fracture dislocation of the ankle is then reduced and the fracture inspected and the stability of the reduction is tested. If internal fixation seems necessary, whatever form is indicated is applied. The wound is then immobilized in a lightly padded cast which extends from the midthigh to the toes and is applied with the knee slightly flexed and with the foot *dorsiflexed to 90°. The immobilization is continued for six weeks, then* the cast is removed and weight bearing is resumed gradually. The swelling is controlled by an elastic bandage or anklet.

Diastasis at the Ankle. Occasionally in fractures at the ankle the inferior tibiofibular ligaments are torn and the malleoli are separated with a broadening of the mortise. If this condition is recognized in the fresh fracture the diastasis can usually be corrected by compression of the malleoli and if a plaster cast is applied snugly over a small amount of padding with the foot in the neutral position and is firmly molded around the malleoli the ligaments will heal by the time the fracture has healed.

If the diastasis is not corrected in the acute stage of the injury open reduction and internal fixation of the tibia and fibula is necessary if a stable ankle is to be obtained. The space between the malleoli is exposed by an anterolateral incision and the soft tissue which fills the space is removed with a knife and curet if necessary and the malleoli are pressed together. Then through a short lateral incision over the distal portion of the fibula a drill hole is made through the fibula and into the tibia, the hole being placed about 1 inch above the distal articular surface of the tibia. Then with a noncorrosive screw about 1½ inches long the two bones

tissue, followed by immobilization and chemotherapy with the wound packed open. In the usual case, however, the procedure is as discussed in the following paragraphs.

Anesthesia. Unless the surgeon is especially skilful in the use of local or regional anesthesia, general anesthesia is to be preferred and is usually started on the operating table, but before the emergency dressing and splint have been removed.

Preparation of the Limb. In operating upon a compound fracture or the femur, or of both bones of the leg, a table which provides support to the limb and provides for traction is helpful. The extremity should be suspended and traction applied. In other bones mechanical traction is not so important. The wound is covered with a sterile dressing, the surrounding skin is scrubbed with soap and water, shaved, then washed with alcohol and ether and a skin antiseptic is applied. The preparation extends entirely around the limb and for an ample distance above and below to permit manipulation. The extremity is draped in such a manner that an adequate exposure may be obtained and the manipulation necessary for the reduction of the fracture can be carried out.

If desired, a tourniquet (preferably a pneumatic tourniquet) may be applied after the extremity has been elevated and drained of blood. This will tend to conserve the patient's blood and makes the operation easier. It should be released before the wound is closed or packed in order that any important bleeding points may be ligated.

Débridement. This is the so-called toilet of the wound and its object is to remove all foreign material as well as soiled and devitalized tissues from the wound and thus prevent the development of infection. In order that function may be restored to the limb the surgeon should avoid the excision of important structures whenever this can be done with safety.

Excision of the Skin Margins. The margin of the skin around the wound is traumatized and contaminated and should be excised. It is grasped with toothed forceps and a thin strip of the free edge is cut off and discarded. This strip is rarely more than one eighth of an inch wide and extends entirely around the wound. Occasionally some of the skin is so damaged that it is obviously devitalized and this devitalized area is also excised. The forceps and knife which have been used are discarded.

Enlargement of the Wound. With a clean knife the wound is enlarged by incisions at its upper and lower margins. The incisions usually lie in the long axis of the extremity and are sufficiently long to permit inspection of the depth of the wound when the margins are retracted.

Débridement of the Wound Proper. The margins of the skin are retracted and a thin layer or strip of the superficial fat and deep and superficial fascia around the margins of the original wound is excised. Then the deep fascia is incised above and below the wound in line with the skin incisions and the margins of the wound are retracted and its deeper portions are carefully inspected. Blood clots and foreign material are removed and the surfaces are carefully cleansed with gauze sponges. Deep pockets are explored and devitalized muscle, areolar tissue, and fibrous connective tissue are excised. Where damaged muscle is exposed in the wound a thin layer of the damaged exposed surface of the muscle is excised

THE OPERATIVE TREATMENT OF COMPOUND FRACTURES

The successful treatment of a compound fracture may demand the highest type of surgical judgment as well as considerable operative ability. The patient may be exsanguinated and in a condition of surgical shock, or he may be in excellent general condition and a good surgical risk. Likewise, the wound may be relatively clean or very dirty and heavily contaminated with bacteria, and may vary in size from a small puncture wound to one or more extensive lacerations with massive destruction of tissue. Depending upon the time which has elapsed since the injury and the severity of the contamination and the amount of destruction of tissue the wound may be mildly contaminated or severely infected.

It is thus evident that the treatment of these cases which has for its objects the saving of the life of the patient, prevention or cure of infection, the healing of the wound, the reduction and union of the fracture, and the restoration of function in the extremity, must be varied to meet the problems presented by the particular case under consideration. However, the treatment does follow certain general principles and an attempt will be made to set these down in such a manner that they can be applied to specific cases.

It is assumed that the patient is in the hospital and that an emergency dressing with or without splintage of the extremity has been applied and that x-rays of the fracture have been made and examined by the surgeon.

It should be determined whether or not tetanus antitoxin has been administered and if not it should be given. If the patient has already been immunized a booster dose of toxoid should be given.

The first consideration is the general condition of the patient and it is now believed that treatment for shock should be instituted before the definitive treatment of the fracture is undertaken. This involves the administration of plasma or of whole blood, if indicated. Now that chemotherapy is available it is good surgical practice to wait for a few hours until the patient has reacted favorably from shock.

Chemotherapy. Penicillin in doses of 400,000 units or more intramuscularly should be given every 3 to 12 hours until after the danger of infection has passed It should be started as soon after the injury as possible. If the patient is sensitive to penicillin or if it is not available, one of the other antibiotics with a broad spectrum should be used. The chemotherapy should be continued for a week or more after the operation until there is relatively little danger of infection.

Is Operative Treatment Advisable? Some compound fractures are small puncture wounds through relatively clean skin, such as selected compound fractures from within, or wounds inflicted by high speed rifle bullets. These may be treated as simple fractures but the patient should have the benefit of full doses of penicillin until the danger of infection has passed (7 to 10 days). All other compound fractures should be operated upon and in case of doubt, operation with a meticulous débridement of the wound is the treatment of choice. If the fracture is frankly infected the operation consists of wide drainage incisions with removal of foreign bodies and devitalized

to permit accurate approximation of healthy tissue for suturing (see Chapter 16). If a joint is involved in the fracture, damaged articular cartilage is shaved off and the synovial membrane is sutured loosely with fine catgut or silk. The ligaments and capsule may or may not be sutured, depending upon whether the wound is to be closed or left open.

Reduction and Fixation of the Fracture. The fracture is now reduced by manipulation of the extremity and of the ends of the fragments which can be grasped with bone holding forceps if necessary. If the fracture is relatively transverse, accurate apposition of the bone ends may be all that is necessary as the reduction may be sufficiently stable to permit the application of a plaster of paris cast without disturbing the position.

If the fracture is oblique or comminuted internal or external skeletal fixation may be indicated. While it is granted that the leaving of foreign material in the wound of a compound fracture increases the danger of infection, experience has shown that with noncorrosive metal (stainless steel, vitallium, or tantalum) this danger is relatively slight and is more than counterbalanced by the added immobilization which can be obtained by the use of screws, wire or plates. The appropriate form of internal fixation should be applied according to good mechanical principles and as little foreign material as practicable should be left in the wound. In compound fractures of the femur or of the leg the fragments may be immobilized with a long medullary nail. Depending upon the severity and condition of the wound the nail may be inserted at the time of the débridement or later at a second or third operation after the wound has healed and the danger of infection has lessened. And the same is true of the use of screws, plates or other forms of internal fixation.

In certain fractures and especially in extensively comminuted or double fractures of both bones of the leg it may be desirable to insert a Steinmann pin or Kirschner wire through each fragment in order that the pin or wire may be incorporated in the plaster cast and maintain the length of the extremity and position of the fragments. If these are to be used the pins or wires are now drilled through each fragment and are placed proximal and distal to the wound. If internal fixation has not been used the limb is held as steady as possible by assistants while the wound is closed, and the dressing and cast are applied.

Final Inspection and Irrigation of the Wound. The wound is now inspected carefully and if a tourniquet has been used it is removed and any fresh bleeding points are ligated. The wound is then washed out again with warm salt solution or preferably with a saturated solution of sulfanilamide or sulfathiazole and the excess solution is left in the wound

Closure of the Wound. The surgeon must now decide whether the wound should be closed with or without drainage or left open with or without drainage. The decision will depend partly upon the practice of the surgeon and partly upon whether or not the surgeon feels that he has performed an adequate débridement and the wound is relatively safe from infection. The time which has elapsed between the injury and the operation and the extent of the damage to tissues and the soiling of the wound are factors in determining whether or not the débridement is adequate and the wound can be closed with relative safety.

and if the remainder contracts when pinched with forceps or bleeds when cut (if a tourniquet has not been applied), then this muscle is considered viable and is not removed even though it may be swollen and infiltrated with blood On the other hand macerated muscle which has lost its blood supply is removed. Shreds of soiled periosteum and bits of areolar tissue which contain fine foreign body particles are excised. Blood vessels are clamped and secured with fine ligatures of silk or catgut and as little blood is lost as possible.

Treatment of the Bone. Loose fragments of bone which are completely detached or those which retain so little periosteal attachment that their circulation is obviously inadequate are regarded as foreign bodies in the wound and are removed. On the other hand all the bone which can be saved is saved in order to preserve the normal length of the limb and the integrity of the bone. Detached or devitalized bone fragments left in the wound of a compound fracture do not serve as bone grafts and usually do more harm than good.

Badly soiled ends of fragments such as those which have protruded from the wound and come in contact with the ground may have dirt forced into the interstices of the bone. These cannot be cleaned and the soiled bone should be excised with a rongeur or bone cutting forceps. This is especially true of cancellous bone. Occasionally in a compound epiphysial separation in which the end of the shaft has protruded from the wound and become soiled, it can be scrubbed with a sterile brush and green soap and water and then replaced in the wound and healing and normal growth may be expected.

The extremity may now be manipulated, if necessary, or the ends of the fragments moved in order to explore the portion of the wound behind the bone Here too, as in the more accessible portions of the wound, foreign material is carefully sought for and removed when found and devitalized tissues are meticulously excised.

Irrigation of the Wound. After the débridement is completed and all foreign material and devitalized tissue have been removed and all bleeding points secured and ligated, the wound is thoroughly washed out with warm physiologic salt solution. This is best done with a two quart irrigating can and a soft rubber tube without a rigid nozzle. The solution is forced into all of the recesses of the wound and any foreign material or devitalized tissue brought to light by the irrigation is removed or excised. About a gallon of warm salt solution is used in order to cleanse satisfactorily the average major compound fracture. If a joint is involved in the fracture the joint cavity is irrigated with unusual thoroughness and the synovial cavity is carefully inspected for retained foreign material.

Repair of Important Structures. The wound is now carefully sponged and all tendons, nerves and muscles which are exposed in the wound are inspected and if they are severed the traumatized ends are excised and the nerve, tendon, or muscle is sutured with fine silk, fine stainless steel wire, or catgut. Muscles are sutured very loosely, just enough suture material being used to hold the ends in contact and care being taken to avoid unnecessary disturbance of the circulation in the muscle. In the repair of nerves and tendons enough tissue is excised from the end of each fragment

11

HEMATOGENOUS OSTEOMYELITIS

FRANK DICKSON

Hematogenous osteomyelitis is a pyogenic bone infection in which the infecting organisms find their way to the bone through the blood stream. Hematogenous osteomyelitis is a quite different condition from the local osteomyelitis which develops in an infected compound fracture, although the local pathology of both is the same.

Incidence. It is difficult to estimate the incidence of hematogenous osteomyelitis. It has been stated that it comprises about 0.5 of 1 per cent of all cases admitted to general hospitals, but in special hospitals for the care of crippled children, the percentage is higher. In 11,819 cases passing through the orthopedic clinic at St. Luke's Hospital, Kansas City, Missouri, there were 291 cases of osteomyelitis, acute and chronic, or 2.4 per cent. Osteomyelitis is primarily a disease of childhood, occurring most commonly between the ages of 3 and 10 years. The disease occurs about twice as frequently in boys as in girls, probably because boys are much more subject to trauma than girls, and trauma is a definite factor in the causation of the disease. It is generally held that osteomyelitis is more frequent among the poor; that is, among those who are less well nourished and lead less clean lives than those in better circumstances. An analysis of 291 cases (in our own series) shows that the social status of 18 per cent of the cases was listed as good; fair in 34 per cent, and poor in 48 per cent. This ratio would tend to support the contention that the poor live under conditions which are favorable to the development of hematogenous osteomyelitis.

Etiology. A staphylococcus is the offending organism in approximately 90 per cent of all cases, usually the hemolytic *Micrococoecus pyogenes* var. *aureus*. The next most common organism found in culture is the streptococcus. Occasionally, the pneumococcus is found. While the staphylococcus is the organism found in 90 per cent of the cases as a whole, in children under two years of age the streptococcus is far more frequently the infecting organism—from 40 to 50 per cent. The higher incidence of streptococcic infection in very young children is probably to be explained on the basis of the antecedent source (upper respiratory tract) and the fact that the infant has relatively less natural immunity to strains of streptococci than to those of staphylococci, according to Green and Shannon. The frequency of streptococcic osteomyelitis in very young children has an important relation to treatment as will be seen later.

Since in hematogenous osteomyelitis the infecting organism reaches the bone through the blood stream, the bone lesion is in reality a secondary focus, the origin of infection being a primary focus elsewhere in the body; at least no valid reason has been advanced to disprove this view. This primary focus must be looked upon as a contributing factor in the etiology

If it is decided to close the wound no attempt is made to close it in layers but the skin, subcutaneous fat and fascia are brought together with a single layer of continuous or interrupted sutures. The wound must be closed without excessive tension and if this is not possible tension incisions may be made on either side to permit closure without excessive tension or a sliding pedicle graft of skin and subcutaneous tissue may be used to cover the bone and tendons.

If tension incisions or a sliding graft have been used the resulting defect may be covered with petrolatum gauze or covered immediately with a split-skin graft which is sutured in place. Or the deeper structures of the wound may be closed and the defect in the skin repaired with a split skin graft which can be applied immediately or a few days later after the raw surface is covered by granulation tissue.

If the wound contains a relatively large dead space or if for any other reason drainage is desirable, this can be obtained by a wick of petrolatum gauze or a rubber tissue drain which is inserted through a stab incision and carried to the depths of the wound before the wound is closed. The drain should emerge in the dependent portion of the limb if possible.

If for any reason closure of the wound is deemed unwise, it is packed open with sterile dry fine mesh gauze or petrolatum gauze with the expectation that within from 5 to 10 days after the débridement the wound will be reoperated upon and if it is found on inspection to be in satisfactory condition it will be closed as described above with or without drainage, if this can be done without too much tension. This is a delayed primary closure. If the wound is found to contain necrotic tissue or pus at the second operation the necrotic tissue is excised and the wound is again packed open and may be closed later by secondary suture or be permitted to heal slowly by granulation.

Pressure Dressing and Immobilization. Whether the wound has been closed or packed open, a pressure dressing should be applied by covering the wound with dry gauze and then wrapping the extremity snugly with a woven cotton elastic bandage; or covered with a thick layer of cotton waste and then wrapping firmly with a gauze bandage. The fracture is then immobilized in a plaster cast which immobilizes the joints above and below the fracture If pins or wires have been applied for external skeletal fixation these are incorporated in the cast; the extremity may be immobilized in a splint with or without traction if the surgeon chooses.

After Treatment. Chemotherapy, supportive treatment of the patient including high protein, high caloric diet, transfusions when indicated, and immobilization with or without dressing of the wound are continued until the wound and the fracture are healed and then efforts are made to restore function to the extremity.

2. Some of the bacteria may lodge in bone, localize, and set up an osteomyelitis;

3. The bacteremia may become a septicemia, which in turn results in a pyemia with abscess formation over widespread areas, including the lungs, kidneys, spleen, liver, and bone.

When the second of these possibilities develops, the bacteremia disappears, usually within 24 to 48 hours, leaving behind only the local bone abscess, and such systemic reaction as may arise from the local pyogenic infection in the bone. When the third course is followed, a septicemia and pyemia develop. This condition has been described as fulminating osteomyelitis, and the outcome is usually fatal. Strictly speaking, it is questionable whether this last type should be considered a true osteomyelitis, since the bone abscesses which develop are only incidental to the general pyemic process; in reality, it is a systemic infection with local manifestations, and not primarily a disease of bone.

OSSEOUS LOCALIZATION

Whatever the difference of opinion may be over septicemia as a complication of osteomyelitis, one fact is generally accepted; namely that bacteria do find their way to bone and set up a destructive process. The area of bone infection occurs with remarkable consistency in the metaphysial region of a long bone. The generally accepted reasons for this localization are that the area has a rather large and stagnant blood supply, is an area of rapid growth, and is subject in growing children to direct and indirect trauma. These reasons seem on the whole to be rather lacking in validity, and fail satisfactorily to explain the reason for fixation in this area. Fraser offers a suggestion which is certainly worthy of consideration and investigation. Fraser holds that the reticuloendothelial tissue, which is present in abundance in the metaphysial area of growing bone, is a factor in determining the frequent localization of the infection in this area. He reasons that since one of the important functions of the reticuloendothelial system is that of acting as a defense mechanism against infection, the localization or fixation of the infection in the metaphysis is the result of the defense activities of the reticuloendothelial cells in this area in their efforts to correct a general infection. On such a basis, the occurrence of a localized or fixation abscess, while it creates a regrettable and difficult situation, so far as the bone is concerned, should be looked upon as a providential occurrence, for it is Nature's method of producing a defense area from which the factors of immunity are organized and developed. Wilensky differs from the view that the metaphysis is the usual fixation point for abscess formation and notes the following fixation points in order of frequency: 1, periosteal vascular plexus, 2, superficial haversian canals in the cortex; 3, metaphysis, 4, main trunk of the nutrient artery; 5, main branch of the nutrient artery. In this series the metaphysis was the fixation point in the vast majority of cases so far as could be determined.

Once bacteria have lodged in the bone, wherever the fixation point may be, they multiply and liberate exotoxins, which diffuse into a surrounding bone, destroy and break down red cells, coagulate plasma, and

of osteomyelitis. The most common primary foci in staphylococcic osteomyelitis are pustules, furuncles, impetigo, and infected blisters and burns. In streptococcic osteomyelitis the primary focus is in the upper respiratory tract, middle ear disease, and in some instances exanthema. The difficulty of getting a clear history in most cases prevents accurate statements as to the primary focus in a great many instances.

Other factors undoubtedly have a bearing upon the occurrence of the disease. The acute diseases of childhood such as measles, chickenpox, whooping cough, and tonsillitis, both by lowering resistance and providing a primary focus, are definite factors. Undernourishment through lowering of resistance becomes a factor.

Mild trauma is a local contributing factor in approximately 25 per cent of reported cases, but it seems logical to conclude, considering the active age at which osteomyelitis is most common and the higher incidence in boys than in girls, that trauma is far more likely to be a predisposing factor in a higher percentage of cases than the admitted 25 per cent. Grover C. Penberthy and Charles N. Weller report trauma as a contributing factor in 40 per cent of the cases in their series. It should be remembered that trauma may be direct or may be caused indirectly by ligamentous and muscle pull exerted at the metaphysial region, where they attach. Mild trauma causes local hemorrhage and tissue damage, thus providing an area of lowered resistance; if coincidently with trauma, there occurs a bacteremia, arising from a primary focus of infection elsewhere, such an area of lowered resistance becomes a favorable location for bacterial implantation and the formation of a secondary focus of infection.

To summarize—in hematogenous osteomyelitis the bone infection results from the localization in a bone of staphylococci or streptococci from the blood stream. Contributing factors are a primary focus of infection elsewhere in the body, lowered general resistance from a variety of causes, and as a localizing factor, mild trauma.

Classification. Hematogenous osteomyelitis may be divided into three stages: 1, the acute form; 2, the subacute form; and 3, the chronic form. Of these three stages the acute is the most important, since it is the period of the disease in which the patient is acutely ill, is in greatest danger of losing his life, and in which early diagnosis and choice of treatment to a great extent determine the final outcome; that is, recovery or passing on into the subacute or chronic stage. It is under the acute stage that basic pathology will be discussed.

Pathology. In discussing the pathology of osteomyelitis, it is necessary to bear in mind that, according to our present understanding of the disease, the focus of infection in bone is secondary to a primary focus of disease elsewhere in the body. The pathway of infection is the blood stream. To meet this accepted basic conception of the origin of osteomyelitis, it is necessary to assume that there occurs a bacteremia produced by a shower of bacteria escaping into the blood stream from a primary focus of infection already present. Once such a bacteremia occurs, clinically it may follow one of three courses:

1, the organisms in the blood stream may be rendered harmless by the defensive mechanisms of the body and no general or local disease develop;

cavity surrounded by granulation tissue. Such sequestrae may be small and scale-like or quite massive and represent a large section of the shaft of the bone.

3. *New Bone Formation.* It is characteristic of pyogenic bone infection that it stimulates the production of new bone so that the picture of bone destruction and new bone formation occurring side by side is the outstanding feature of the x-ray findings in pyogenic hematogenous osteomyelitis. New bone production is, of course, the result of the activity of living osteoblasts adjacent to the area of inflammation. The amount and arrangement of the new bone formed depends upon the location and extent of the destructive process.

As time goes on, in the majority of cases the gradual disintegration of the dead bone and infected bone continues, and the pus thus continuously formed escapes through sinuses which penetrate the surrounding new bone and discharges on the surface. In a certain percentage of cases where the infection is low grade, the area of infection may be walled off by the new bone surrounding it and become silent. Such areas may remain dormant for long periods of time, but sooner or later they are likely to light up and cause a recurrence of the disease. So long as such walled off areas are present in a bone and can be demonstrated by x-ray, we cannot speak of the osteomyelitis as cured, but only as quiescent. How long pyogenic organisms may remain dormant is not known, but unquestionably they may do so for years. In the series reported, there are several examples extending over 15 to 30 years. It is also true that not all of these walled off areas will become active, but they are always under suspicion.

CLINICAL PICTURE

The clinical picture about to be presented is not in complete conformity with views widely held. It is, however, a concept of hematogenous osteomyelitis which seems to fit the situation as it has presented itself in our clinic over the period of the last 25 years.

The patient with acute hematogenous osteomyelitis is usually a child or an adolescent, although osteomyelitis does occur in the adult. There may be a history of an already existing infection, such as a boil or furuncle, upper respiratory infection, or middle ear disease. A history of trauma is elicited in about 25 per cent of the cases or more. Unfortunately, an accurate history is difficult to obtain, since the parents' statements are often unreliable. With this background, although the disease varies greatly in severity, it is usually possible to differentiate two types of onset and, we believe, two forms of the disease, based upon the mode of onset and the clinical course. At least the character of the onset of the symptoms should be definitely suggestive.

In the usual case the first symptoms are pain and stiffness in the affected region, sometimes in the upper, but more frequently in the lower extremity. There is disinclination to move the extremity, and it is carefully guarded against jarring. Pain gradually increases in intensity, fever develops, and a mild chill may occur. At this time the limb is usually held in a position of slight flexion of the joint nearest which the infection is located. Flexion

cause the death of leukocytes. Since this process occurs in tissue which is dense and hard and lacks the elasticity of soft tissue, it disperses rapidly. There occurs extensive thrombosis of vessels, and so there is less opportunity for the defense cells of the organism to wander into the inflammatory region to overcome infection and aid the connective tissue cells in walling off the infection. Leukocytes appear in large numbers, but they are fighting a losing battle against the exotoxins and are destroyed, and a proteolytic ferment is liberated which autolyzes or destroys the dead bone and an abscess is formed.

Once the metaphysis has become the site of an abscess, it may be walled off and little destruction result; or infection may spread to the epiphysis, diaphysis, or the adjacent joint or to all three. Spread of the infection into the epiphysis may occur by direct extension. This is resisted, however, by the almost avascular epiphysial cartilaginous plate. Infection may spread to the diaphysis by direct extension, but infection usually spreads by way of the subperiosteal space. When infection follows this pathway, the abscess penetrates the thin cortex of the metaphysis and enters the subperiosteal space in which it spreads along the diaphysis which it invades by way of the periosteal vessels, eventually reaching the medulla through the haversian canals. Spreading subperiosteally, the abscess may extend completely along and surround the shaft, causing serious interference with the blood supply which becomes an added factor in the necrosis which occurs.

Infection of the adjacent joint from a metaphysial focus may occur by direct extension through the epiphysis or by pus which has found its way into the subperiosteal space, dissecting up the capsule of the joint. When the metaphysis is intracapsular, the joint may be infected by penetration of the infection through the cortex of the metaphysis directly into the joint. Since most metaphyses are extra-articular, pyarthrosis is a less common complication of osteomyelitis than would be expected. The hip is a notable exception, as the metaphysis of the upper end of the femur is entirely intracapsular; this explains why infection of the hip is the rule in acute hematogenous osteomyelitis of the proximal end of the femur. The ankle and knee joints, however, are on the other hand rarely involved.

The changes which occur in the bone in the course of osteomyelitis, the result of pyogenic invasion and destruction, are: 1, necrosis of bone; 2, sequestration or throwing off of dead bone; and 3, new bone formation—involucrum.

1. Necrosis. Evidence of necrosis of bone may be seen in an x-ray from 10 to 14 days after the onset of the disease. The picture shows a mottled or moth-eaten appearance due to scattered areas of bone destruction and absorption. Necrosis is caused mainly by the necrotizing effect of the exotoxin liberated by the bacteria, but thrombosis of vessels closing off the blood supply to certain areas probably plays a definite part.

2. Sequestration. After the acute process has subsided, the devitalized bone is surrounded by living bone. This living bone may gradually surround the dead bone, absorb it, and replace it by living bone by a process known as creeping substitution. More frequently, however, the dead bone separates from the living bone and becomes a sequestrum which lies in a

cavity surrounded by granulation tissue. Such sequestrae may be small and scale-like or quite massive and represent a large section of the shaft of the bone.

3. **New Bone Formation.** It is characteristic of pyogenic bone infection that it stimulates the production of new bone so that the picture of bone destruction and new bone formation occurring side by side is the outstanding feature of the x-ray findings in *pyogenic hematogenous osteomyelitis.* New bone production is, of course, the result of the activity of living osteoblasts adjacent to the area of inflammation. The amount and arrangement of the new bone formed depends upon the location and extent of the destructive process.

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of the joint may be permitted without protest, but *extension of the joint is always painful and resisted.* The temperature rises rather rapidly to 102 to 104 degrees with a proportionate increase in the pulse rate, 120 to 130 per minute. The skin becomes hot and dry, the face flushed, tongue coated, and the urine concentrated. In an interval of a few hours to three days, the pain in the affected region becomes intense, and the patient will not permit the limb to be moved or even touched without protest. Restlessness and exhaustion due to toxemia develop. With continued high temperature there is a decrease in the intake of fluids, and signs of dehydration appear.

Locally, there is definite tenderness to palpation over the involved area, usually in the metaphysial region, if a long bone is the site of infection. This area of sharply localized tenderness makes its appearance early in the disease and before local swelling, redness, and warmth are evident. A careful, gentle, patient investigation, using the tip of one finger will usually localize the tender point which should be most carefully sought for, since it is the most important diagnostic sign of osteomyelitis. Later the affected region becomes swollen, red, hot, and edematous, and the pain and tenderness becomes more diffuse. Fluctuation does not, as a rule, appear until the bone abscess has ruptured through the periosteum and pus escapes into the surrounding soft parts.

Such a clinical picture with evidence of general toxemia and definite signs pointing toward a localized bone abscess is typical of the usual form of hematogenous osteomyelitis. The patient is ill, sometimes seriously ill, but the outstanding feature of the illness is evidence of a localized infection in one bone, rarely more.

The second type of onset differs from that described above and should suggest, we believe, a different type of disease. The onset is usually abrupt and is initiated with a chill, although there may be a prodromal period of one to two days during which time the patient complains of not feeling well, is listless, and has no appetite After the chill, there is a rapid rise of temperature, the pulse becomes rapid and running, the patient is restless and exhausted, dehydration rapidly develops, and delirium is not infrequent. The patient is seriously ill and gives evidence of an overwhelming toxemia. There may be localizing signs of pain and tenderness in the upper or lower extremity, but these are not outstanding and may be absent or masked by the serious systemic reaction. Cases presenting such severe constitutional symptoms with few or no localizing symptoms are in all probability suffering from a septicemia, which is the real disease. If the septicemia persists, there follows a pyemia with abscess formation in various organs and tissues of the body, including bone. That this condition should be called an osteomyelitis is, we feel, decidedly questionable, since such abscesses as may occur in bone, usually not single but multiple abscesses, seem to be incidental to the septicemia and pyemia, in other words, they are only part of the general picture of multiple abscess formation. This type of osteomyelitis has been called the fulminating type; it too frequently resists all efforts at control and usually ends fatally.

LABORATORY FINDINGS

The blood picture in acute hematogenous osteomyelitis depends upon the *duration and severity of the infection.* As a rule, in the ordinary case there is a leukocytosis of from 15,000 to 25,000 per cubic millimeter. With severe and overwhelming infection, there may be little or no increase in the leukocyte count. Failure in leukocytic *response is a grave sign, for it* suggests that the patient's resistance is low, and the effects of the infection have overcome the defense mechanisms of the body in which case the prognosis is grave. The differential count usually shows a predominance of polymorphonuclear leukocytes.

Early *in the disease* the red blood cells show little effect, but as the disease progresses anemia develops, probably due to the destruction of red cells by the toxins liberated.

Blood cultures are important both in indicating the form of the infection and in determining the presence of a septicemia. A blood culture should be made on all patients in whom there is a suspicion of bone infection on admission and should be repeated at intervals. In the type in which a bacteremia occurs and a localized bone abscess develops early, the blood culture *may* be and *frequently* is negative. A positive blood culture persistently present indicates a true septicemia, and the outlook is extremely grave.

X-RAY FINDINGS

In acute hematogenous osteomyelitis the immediate findings on x-ray examination are negative and remain negative until changes in the organic elements of the bone have progressed sufficiently to be demonstrable in the x-ray film. It is the absence of changes in the bone on x-ray examination early in the disease which has frequently been responsible for failure to make a correct diagnosis by those unacquainted with this fact. The period at which *positive x-ray findings appear varies with the age of the* patient, the virulence and the extent of the infection, and the density of the soft parts which overlie the bone.

In young children from six months to two years of age, x-ray evidence of changes in the infected bone appear within a few days; these changes have the appearance of an area of rarefaction in the metaphysial region and very early subperiosteal bone formation which tends to extend rapidly along the shaft of the bone and give the impression that there will follow complete sequestration of the entire shaft.

In older children and in adults, the first bone changes appear in from 8 to 14 days. These changes are a combination of bone destruction and new bone formation. *Bone destruction appears as areas of rarefaction in* the metaphysial region, giving a *mottled or moth-eaten appearance.* New bone formation appears as subperiosteal bone. At times with a virulent, necrotizing staphylococcic infection, the destruction of bone is rapid and extensive, and new bone formation does not appear for weeks or even longer.

As the disease becomes more chronic, the areas of destruction become greater, more new bone is laid down, and the bone becomes irregular in

shape and thickened. Eventually if infection continues, sequestrae are formed, and new bone production, going on actively, forms an involucrum. When the disease persists over months or years, cavities filled with granulation tissue, pus, and sequestrae of various sizes develop in the bone. These cavities are surrounded by a layer of dense, eburnated bone which forms the walls. Such cavities are usually located in the metaphysis of the bone but frequently extend to the diaphysis. In the metaphysis the cavity extends down into the cancellous bone of the region and forms a diffuse area infiltrating the entire end of the bone. This area is made up of small abscess cavities containing minute sequestrae. In the diaphysis the destructive process extends into the medullary cavity and destroys the bone marrow for varying distances, the destroyed areas being usually separated from the normal marrow by a definite wall or plug. Sequestrae lying in these cavities are visible as dense masses of bone with irregular outlines which are clearly demarcated from the surrounding lighter area of the abscess cavity.

DIAGNOSIS

In children in the age group of from 3 to 15 years, any acute illness characterized by a sudden onset, high temperature, pain over a bone in the vicinity of a joint, and a high leukocyte count, hematogenous osteomyelitis should be strongly suspected, and a careful examination for local tenderness over a bone end be carried out. It is difficult to understand the frequency with which this condition is overlooked, since its incidence is moderately frequent and its distribution wide. The outstanding diagnostic finding is localized tenderness over the bone, usually a long bone, and most commonly over the metaphysis. This localized tenderness can usually be disclosed by a patient, gentle, and searching examination.

The condition which most closely resembles osteomyelitis is pyarthrosis, the evident enlargement about the joint with the swelling confined to the outlines of the synovial pouch, limitation of motion in the joint in all directions—not merely in extension—and the less toxic early course of the disease should make it possible to differentiate between these two conditions.

Cellulitis is frequently mistaken for osteomyelitis, as its onset is very similar; that is, with chills and fever. In cellulitis, however, the redness and edema appear very early; in fact, coincident with the systemic reaction, the tenderness is over the entire area of involvement, not definitely localized, the pain is very much less, of a different character, and the toxemia not nearly so marked.

PROGNOSIS

The prognosis in acute hematogenous osteomyelitis depends upon whether the case is one in which there is a transient bacteremia with the formation of a local bone abscess, or whether it is one in which a true septicemia is present with pyemia. In the former the prognosis as to recovery is good; in the latter it is grave, and a fatal outcome is a frequent result. Because these two types have never been separated in statistical

studies, figures on the mortality rate in osteomyelitis vary widely from 2 per cent up to 30 per cent. Obviously with such wide variation in figures, quite different types of cases are being dealt with. In the series present there were 32 cases of acute osteomyelitis with a mortality rate of 12.2 per cent. All but two of the fatal cases in this group were the fulminating form with septicemia and positive blood cultures. The average mortality, as nearly as can be determined in the ordinary case, is somewhere around 10 to 15 per cent. The mortality in the septicemic type is well over 50 per cent, perhaps higher. There is great hope, however, that with the use of antibiotics and the sulfonamides, the mortality rate in the fulminating type will be materially decreased. The mortality rate in infants is high. Green and Shannon report a general mortality rate of 21 per cent with a rate of 45 per cent in those under six months of age.

The prognosis so far as healing of the local bone focus is concerned is bad. A great majority of the cases three years of age or older pass on to the chronic stage; in infants, however, there is little tendency for the disease to become chronic. The difference in the behavior of bone in extremely young children compared with older children and adults has been considered to be due to three factors: 1, the infection in young children is frequently a streptococcus, which causes less bone destruction than does the staphylococcus, 2, the large cancellous spaces in the infant allow the infection to pass more readily from the site of origin into the subperiosteal space, and the periosteum being loosely attached in the infant, separates readily or in some instances ruptures, thus affording early drainage for the infection and insuring minimal bone destruction; and 3, dead bone in young children absorbs very quickly, and new bone formation is rapid. The tendency to chronicity is largely due to inadequate treatment in the acute stage. It is to be hoped that a better understanding of the disease and its early treatment combined with the use of antibiotics and chemotherapeutic agents will change this picture to a much more favorable one.

TREATMENT

The management of hematogenous osteomyelitis is a surgical problem of some complexity, since the condition must be dealt with in the acute stage, the subacute stage, and the chronic stage. There is at the present time considerable divergence of opinion as to the proper procedure to follow in each of these three stages, but perhaps the most controversial question is treatment of the acute stage. The differences of opinion which exist over the type of treatment to be followed in acute osteomyelitis could speedily be harmonized, we believe, if a uniform conception of the fundamental pathology could be established; the difficulty in reconciling the differing points of view lies apparently in the fact that advocates of this or that form of treatment are not always speaking of the same condition. If it were recognized that from the beginning, acute hematogenous osteomyelitis can, as a rule, be separated into that type in which the constitutional symptoms are comparatively mild, while the signs of local infection in the bone are *definite* and outstanding, and into a second type in which the constitutional symptoms are severe and overwhelming, while

the local symptoms of abscess formation are absent or masked by the general symptoms, much confusion could be avoided. In the first type the picture is that of a local infection, associated with which are the constitutional symptoms concomitant with the localized infection. In the second type, the picture is that of a systemic infection, a septicemia, as a consequence of which a pyemia develops with multiple abscess formation in bone and other tissues. The basic pathology and clinical course of these two types are entirely different, we believe, and consequently each demands a different kind of treatment. What would be sound treatment in one may be unsound in another. This fact should be recognized in determining what form of treatment is to be followed in the acute stage of the disease.

For the purpose of treatment in the acute stage of hematogenous osteomyelitis, the cases should be divided into two groups: 1, infants, that is children under two years of age; and 2, children over two years of age, adolescents, and adults.

The treatment of osteomyelitis in infants should be conservative. The different reaction to infection which bones in children display as compared with adult bones has been commented upon under prognosis; it is this difference in behavior which makes conservative treatment so successful in infants. The care of the patient rather than the osteomyelitis is the important consideration. Supportive treatment, prevention of dehydration, and immobilization of the affected extremity are the essentials of management.

The unquestioned bacteriostatic effect of the antibiotics and chemotherapeutic agents should be taken advantage of at once. Penicillin because of its apparently greater potency and lack of toxic effect, is preferred. It should be given in adequate dosage—125,000 to 150,000 units or even much larger doses intramuscularly each 24 hours. If penicillin is not available, the sulfonamides, preferably sulfadiazine, should be used in adequate dosage. At times both may be given. In our enthusiasm over antibiotics there is danger that the sulfonamides will be forgotten; this would be most unfortunate, as they have a large field of usefulness.

Antistaphylococcic serum should be administered if the infection is due to the staphylococcus and if the serum is available.

Locally, the treatment should be conservative. As a rule, the delicate periosteum ruptures early, and pus escapes into the surrounding soft parts. When this occurs, simple aspiration through a large needle will usually take care of the situation If not, drainage of the abscess should be carried out. If temperature and pain persist, the subperiosteal abscess probably has not ruptured, and an incision down to and opening the periosteum should be made. A small opening into the bone may be made at this time if it seems advisable. Unquestionably, the less surgery used in infants, the better is the outcome Sequestration is rare in infants, and if it does occur, it should be taken care of at a later date. If the patient survives the acute illness, the prognosis is excellent with little probability of future trouble.

The treatment of the acute stage of osteomyelitis in children over two years of age, adolescents, and adults is not the comparatively simple problem that it is in infants. The less favorable histologic and anatomic structure of the more mature bone makes it more vulnerable to attack by the patho-

genic organisms and provides less effective and rapid drainage for pus into the subperiosteal space. Consequently, more pronounced toxemia is present, more bone destruction takes place, and there is a definite tendency for the acute condition to pass over into the subacute or chronic stage. In this group, treatment should be carried out along several lines—general supportive measures, chemotherapy, administration of staphylococcic antitoxin, and management of the local bone disease.

General treatment is very important, since the toxemia and dehydration are frequently pronounced. Relief of pain by morphine or codeine and immobilization of the affected part are imperative. Dehydration is combated with forced fluids by mouth or intravenous administration of 300 to 500 ml. of saline glucose. If the patient is definitely toxic and the blood count shows definite anemia or low hemoglobin, a blood transfusion of from 400 to 500 ml. of blood should be given, depending upon the age of the individual, and repeated as indicated.

Chemotherapy. In this age group as in infants, the antibiotics and chemotherapeutic agents should be used from the start. There can be no question but that chemotherapy is the most powerul agent we have at our disposal in combating osteomyelitis, so much so that it is changing the course of the disease into a much more favorable channel. Penicillin should be used in adequate dosage at least 125,000 to 150,000 units every 24 hours intramuscularly. If, however, the causative organism can be isolated and its sensitivity to the antibiotics determined the appropriate antibiotic is then given in adequate doses. It seems questionable whether prolonging the administration of an antibiotic beyond 10 to 14 days is worthwhile, as there is a definite possibility of the infecting organism becoming fast to the particular antibiotic used if the medication is continued beyond this time. It might be wise to change to one of the sulfa drugs at this time if further medication is required. If the sulfa drugs are used, sulfadiazine should be administered by mouth with 2 to 4 gm. as the initial dose, depending upon the severity of the infection, and 1 gm. every four hours should be the sustaining dose. The blood concentration of the drug should be from 4 to 6 per cent, and sufficient dosage should be given to maintain it at this level. The amount of the drug given is based upon the weight of the individual. The accepted dosage is about 0.3 gm. per kilo or 2.2 grains per pound, as the sustaining dose. This would mean, of course, that the dosage in children should be very much lower than those listed above. Fluids should be given freely during the administration of the sulfonamides to minimize any possibility of kidney damage. Since the prolonged administration of the sulfonamides is not without danger, it should be stopped as soon as the infection is under control. It is quite safe, so far as our experience goes, to administer the drug over as long a period as two weeks, if necessary, but under careful supervision. Recent investigations seem to indicate that the sulfonamides, particularly sulfadiazine, sulfathiazole, and sulfamerizine administered in combination increases their effectiveness in smaller concentrations. This fact should be borne in mind.

Staphylococcic antitoxin has not been very widely used, although at the present time highly concentrated and purified serum is available. Investigators, notably Shands and Baker, report very excellent results with its

use. Baker and Shands report a reduction of mortality from 70 per cent in 30 cases in which the antitoxin was not used to a mortality of 25.7 per cent in 35 cases in which it was used. These authors believe that the antitoxin should be given in cases in which the white blood count shows a relative decrease in the segmented forms and a relative increase in the nonsegmented forms (20 per cent or more) of the polymorphonuclear leukocytes. It seems logical, however, that since there is no danger in the administration of the antitoxin, it should be given to all extremely toxic cases. The high mortality rate reported by Baker and Shands would indicate that they were dealing in their series with a staphylococcic septicemia with profound intoxication. The few cases in the series report in which antitoxin was used were of this type, and its administration failed, unfortunately, to alter the course of the disease and save the patient's life. Certainly, in view of the favorable reports in the literature, staphylococcic antitoxin should be administered when available.

Specific agents to control infection at the present time have not established themselves in a positive position. Toxoids which increase the immunity of the patient are too slow to be helpful; it requires about two weeks before effective immunity can be established. Bacteriophage is still on trial.

Local Treatment. There is some difference of opinion today over the proper treatment of the local bone focus. The chief difference of opinion is over the question of drainage; that is, whether the focus should be drained or should not be drained. This controversy has become so heated that it seems likely to confuse the whole problem of treatment to a disastrous extent. It seems worthwhile, therefore, to attempt to place this question of drainage on a rational basis with the hope that some good may come of it. There are two distinct schools of thought on this point—those who consider osteomyelitis an acute surgical emergency which demands drainage at the earliest moment consistent with safety and those who maintain that drainage is contraindicated and is detrimental. The advent of antibiotics and chemotherapeutic agents with their bacteriostatic effects has added fuel to the flames of this controversy. Those who advocate nonintervention base their position on two premises: 1, the belief that the focus in the bone is a source of antibacterial influences which are effective in combating the general infection, and, therefore, it should not be disturbed; and 2, the belief that the natural defense mechanisms of the body will take care of the systemic and local infection. Those who advocate early drainage maintain: 1, that the problem is a surgical one and is not entirely one of immunology; that the general resistance of the patient cannot be expected to increase rapidly enough to combat successfully the local and general infection; and 2, that the undrained local infection in bone tends to spread and to destroy more and more bone and, therefore, surgical drainage is necessary and should be carried out at the earliest moment consistent with sound surgical judgment. While individual opinion based on experience may be for or against drainage of the bone focus, one fact seems fundamental and should be generally accepted; this is that a localized bone abscess, which is the usual type of osteomyelitis, is one thing, and a septicemia with multiple abscess formation is another. When dealing with

a localized bone abscess, surgical drainage is a sound procedure. When dealing with a septicemia with inconclusive signs of localized abscess formation in bone or with signs of multiple abscess formation, surgery has no place in treatment and may possibly accelerate a fatal termination. From a careful study of a wealth of material and reports, it seems probable that this differentiation has not always been made, and many cases of septicemia have been operated upon which should never have been subjected to surgery. This has led many to conclude that surgical drainage is unwise and harmful, a faulty conclusion which would be rectified to a large extent, we believe, by a more careful segregation of cases by type in statistic records.

In view of the fact that it is an established surgical principle that a focus of infection with tissue destruction must be drained, it does not seem logical to depart from this principle in dealing with an abscess in bone. Bone is a tissue which, when infected, has little defense and poor recuperative power except in infants, and for this reason would seem to demand drainage even more urgently than an abscess of the soft parts in order to relieve the general toxemia, reduce to a minimum the amount of bone destruction, and lessen the danger of reinfecting the blood stream with the probable development of metastatic abscesses. On this basis, our position in treatment has been drainage of the local bone abscess at the earliest possible moment; that is, at the earliest moment that the patient's general condition will permit, except in those cases in which the acute onset with a chill, the grave constitutional symptoms, particularly positive blood culture, and lack of signs of a definite bone localization indicate a septicemia.

The time selected for drainage is determined by the patient's general condition. If the general condition is relatively good and dehydration has not set in, immediate operation may safely be performed. If there is evidence of grave toxemia and dehydration, the operation should be delayed until rest, the administration of saline glucose, and blood transfusions convert a poor surgical risk into a safe one; this may be a matter of 24 hours or a week or more. In the meantime blood cultures should be made frequently to determine whether a septicemia is present and if so, its course. During such a period of waiting, and before the sensitivity of the causative organism is determined, penicillin in large doses should be administered.

When the decision to drain has been reached, it should be thoroughly established but with a minimum of surgery. An adequate incision should be made in the soft parts over the point of greatest tenderness, and, following muscle planes as far as possible, carried down to the bone, which should be thoroughly exposed. Ordinarily, a window about 1 inch square should be removed from the cortex of the bone with an osteotome for adequate drainage. If haste is desirable, one or two drill holes may be substituted for window drainage. Incising the periosteum without opening the cortex of the bone does not provide adequate drainage The wound should be lightly packed with petrolatum gauze or gauze soaked with Dakin's solution. We prefer the latter. The extremity is then immobilized in plaster, or if the patient is quite ill, by traction or sandbags.

It should be realized that the establishment of drainage in acute osteomyelitis does not ordinarily bring about a dramatic ending of the clinical

use. Baker and Shands report a reduction of mortality from 70 per cent in 30 cases in which the antitoxin was not used to a mortality of 25.7 per cent in 35 cases in which it was used. These authors believe that the antitoxin should be given in cases in which the white blood count shows a relative decrease in the segmented forms and a relative increase in the nonsegmented forms (20 per cent or more) of the polymorphonuclear leukocytes. It seems logical, however, that since there is no danger in the administration of the antitoxin, it should be given to all extremely toxic cases. The high mortality rate reported by Baker and Shands would indicate that they were dealing in their series with a staphylococcic septicemia with profound intoxication. The few cases in the series report in which antitoxin was used were of this type, and its administration failed, unfortunately, to alter the course of the disease and save the patient's life. Certainly, in view of the favorable reports in the literature, staphylococcic antitoxin should be administered when available.

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embers likely to be fanned into activity by such breezes as lowered resistance or local trauma to the quiescent area. Our observation has convinced us that sooner or later a very large percentage of these quiescent foci do become active. If it were always possible to diagnose acute hematogenous osteomyelitis early, that is before any local abscess has formed, there is every reason to expect that the infection could be controlled by chemotherapy and antibiotics and drainage would be unnecessary. Unfortunately, such early diagnosis is rarely possible, so that generally it must be accepted that some bone destruction has already taken place before chemotherapy can be instituted. To rely upon chemotherapy or antibiotics alone to sterilize and eliminate an already developed abscess, is asking too much of these agents. At the present time, then, our experience has convinced us that the preponderance of evidence is in favor of early drainage of the osseous focus in acute hematogenous osteomyelitis except in the fulminating type with septicemia and pyemia. Over the past three or four years, numerous reports have appeared in the literature dealing with the treatment of acute hematogenous osteomyelitis using penicillin without drainage. A careful appraisal of these reports shows that surgical drainage was necessary in from 20 to 30 per cent of the cases so treated in the acute stage or shortly thereafter. How many will later require surgical interference for the relief of chronic foci which have persisted, time alone will tell.

Fulminating Form. Septicemia with multiple bone abscess formation has been described as fulminating osteomyelitis. The outstanding features of fulminating osteomyelitis are a continued septicemia and multiple abscess formation in soft tissue and bone. The problem of treatment is quite different from that presented by the usual form in which a single bone abscess constitutes the sole pathology. The septicemia is the condition which must be met, and its elimination is the pressing emergency.

Penicillin administered intravenously, blood transfusion, and supportive treatment in every form must be our main reliance. The usefulness of the sulfonamides should not be overlooked, and these drugs in some form may be advantageously used in combination with antibiotics in most cases.

Surgery has no place in treatment at least until the septicemia has been controlled. No good purpose can be served by draining a single bone abscess when multiple abscess formation has in all probability already occurred in both bone and soft tissue. Furthermore, the added insult of a surgical operation may be responsible for a fatal outcome. If the patient survives, drainage of one or more abscesses may be necessary, but this must be postponed until the general condition is favorable.

Subacute Stage. As stated, with the use of antibiotics and chemotherapy, early drainage, and adequate aftercare, a fair percentage of cases will heal by granulation and will give no further trouble. Unfortunately, in a large percentage of cases, either because early drainage has not been instituted or because of massive bone necrosis, healing does not take place, and the condition remains more or less active with or without the formation of draining sinuses. When healing fails to take place in from three to six months, the condition has passed into the subacute stage. Unless these subacute cases are treated radically, the condition passes over to the

symptoms. The bone involvement is but a local manifestation of a systemic infection, and symptoms will persist until the defensive mechanisms of the body gain the upper hand. Continued elevation of temperature for a few days, then, does not indicate an extension of the condition. Continued improvement in temperature and symptoms, however, is to be expected, and failure to follow this course should arouse a suspicion of inadequate drainage or the development of additional foci. In a fair percentage of cases with early drainage and the administration of penicillin or the sulfonamides, extensive necrosis of bone will not occur, and the wound under careful aseptic dressings (Dakin's irrigation or packing with sterile petrolatum gauze) will heal by granulation.

Twenty-eight of the thirty-two cases of acute hematogenous osteomyelitis in this series had early drainage and Carrell-Dakin treatment. Seven, or 28.5 per cent healed without additional surgery. Four of these seven cases were treated after the introduction of the sulfonamides but before the introduction of penicillin. Grover C. Penberthy and Chas. N. Weller report 19 cases treated by early drainage and the systemic administration of sulfanilamide. Of these only two had later sequestration and required additional operation.

It is only fair to state that today there is definite trend against early drainage of the localized bone abscess in hematogenous osteomyelitis. This position has received additional impetus with the introduction of antibiotics and chemotherapeutic agents. The bacteriostatic effects which these agents exert seem unquestionably to bring about the disappearance of the constitutional symptoms and control the local bone infection in some but not in all cases. These agents, however, can have no effect upon the local bone destruction which has occurred before the infection was brought under control, and the necrotic tissue which formed remains as a possibly quiescent but certainly unhealed focus in the bone. So long as the x-ray reveals definite areas of bone destruction and sequestrum formation, no matter how silent the area may be clinically, the case cannot be spoken of as cured but only as one which shows a clinical recession with a quiescent bone focus. Such quiescent areas may remain dormant for years and in some cases permanently. However, an examination of a number of cases treated by the administration of antibiotics and chemotherapeutic agents without drainage has shown that in practically all a careful x-ray examination revealed persistent areas of bone infection and destruction which are readily differentiated from the surrounding normal bone. Such areas constitute potential sources of trouble in the future. Wilson and McKeever report three cases treated without drainage and the administration of the sulfonamides with subsidence of acute symptoms in which several months later drainage was established because of persistent local induration. Thick, soft, hyperplastic bone was encountered and granulation tissue was found in the medullary canal when drainage was established. Smears and cultures revealed staphylococci. These findings clearly indicate that such quiescent foci are not sterile but harbor dormant bacteria capable of activity. Treating a bone abscess with antibiotics and chemotherapeutic agents and without drainage may result in putting out the fire, but the ashes remain, and only too frequently, ashes which have

be elevated, it cannot be expected to cope with the problem of an infected rigid walled cavity. It is known that the bacteriostatic effects of antibiotics and chemotherapeutic agents are inhibited by pus and necrotic tissue. Therefore, little help is to be anticipated from these agents until this necrotic tissue has been removed. Furthermore, the poor vascularity of the tissues surrounding the focus makes it difficult for drugs to reach the infected area through the blood stream in sufficient concentration to be effective. Antibiotics, potent as they seem to be as a sterilizer of infection, are under the same disadvantage as the sulfonamides in getting to the site of the infection because of the poor vascularity of the surrounding tissue. However, all of these agents can, under favorable conditions, help materially in bringing about healing by aiding in the sterilization of the infected area if adequate surgery is employed to bring about conditions amicable to their action.

The surgical operation performed in removing all of the infected and necrotic tissue and thoroughly cleaning out of the chronic or subacute osteomyelitic cavity should be bold and thorough. Notwithstanding the fact that some qualified surgeons hold that doubtful bone may be left behind, it has been our experience that this is unsound, and that unless all infected as well as dead bone is removed, the operation will be a failure. It is true that the condition will be improved, perhaps vastly so, but complete healing will not occur, and within a few weeks or months, sinuses will develop and another operation or perhaps several will be necessary before healing can be anticipated.

Fig. 11-1 Injection of sinus with methylene blue.

When planning a surgical attack on an osteomyelitic cavity, the operation should be preceded by a careful x-ray study of the area to be attacked. The operation is preferably performed under a tourniquet to avoid excessive loss of blood. If sinuses are present, it is our custom to inject these with methylene blue (Fig. 11-1), which stains all dead and necrotic tissue and is a guide to the extent of the area and the amount of bone which must be excised. A generous incision should be made in the soft parts to expose the area to be attacked, since almost invariably a larger area of bone must be removed than is indicated by the x-ray (Fig. 11-2). Using osteotome or gouge and mallet, the overlying bone should be cut away sufficiently to uncover the entire cavity. In doing this, a large amount of

chronic stage with increasing destruction of bone, chronically draining sinuses, and frequently metastatic foci. If, however, the situation is intelligently met and a thorough clean-up of the focus is carried out, healing will be secured within a reasonable period of time, and the patient will be saved months and even years of chronic bone infection.

The treatment of the subacute stage of hematogenous osteomyelitis is largely surgical, since the constitutional symptoms will have disappeared, and the local area of bone infection and destruction is all that remains. Such general measures as are indicated to improve the patient's general condition should be carried out. The surgical measures which are employed are wide incision and complete removal of all dead and infected bone, since only by complete removal of all necrotic bone and infected and fibrosed soft tissue can healing be brought about. The surgery required and aftercare of the wound in the subacute stage are practically identical with that employed in the chronic stage except that, as a rule, much less extensive removal of bone is necessary, so the details of treatment will be omitted here and be considered under the treatment of the chronic stage. Operative interference in this subacute stage is frequently advised against on the grounds that new bone will be destroyed along with the infected bone, the reparative process interfered with, healing delayed, and the bone weakened. This fear is, in our opinion, unfounded, since accelerated bone regeneration and repair follow the elimination of infection, and with proper protection, the danger of a pathologic fracture is nil.

Chronic Stage. When the chronic stage has been reached, we have a situation in the involved bone which presents a very definite problem. As a result of disease, there has developed in the bone, usually in the metaphysis but frequently extending into the diaphysis and medullary canal, a cavity filled with infected granulation tissue, sequestrae of various sizes, and pus. Usually surrounding this cavity in part is new formed bone (*involucrum*), *which walls off the infected area and helps form* a cavity with rigid walls, which Nature is unable to obliterate. In addition, the new bone laid down in the haversian canals increases the density of the bone adjacent to the cavity; with this increased density goes decreased organic material in the bone and a decrease in its blood supply. Such dense or eburnated bone is, because of its decreased vascularity, not only less able to resist and destroy bacterial infection, but for the same reason loses its ability to form new bone. Furthermore, because of long continued suppuration and sinus formation, the soft tissues surrounding the infected area in the bone are largely made up of fibrosed and poorly vascularized scar tissue. The picture presented, then, is that of a rigid walled cavity, filled with infected material, adjacent to which is sclerotic bone with minimal recuperative capacity, and finally, surrounding all of is a mass of scar tissue, poorly vascularized, and so an unsatisfactory source of nourishment to the bone and with poor healing properties. It is quite evident that to correct the situation and bring about a permanent cure, radical surgery is required. There is no medication, including toxoid, antitoxin, sulfonamides, or antibiotics, which has any beneficial effect on the course of the disease, except as an adjunct to adequate surgery. The reason for this is quite clear. No matter how high the defense mechanism of the body may

normal bone must be sacrificed. This is necessary if the cavity is to be exposed throughout its extent. When the cavity has been laid open, it should be thoroughly cleaned out by removal of all granulation tissue, sequestrae, and necrotic bone with gouge and mallet (Fig. 11-3). Curetting such a cavity is ineffective and can only result in an incomplete operation. A curet should be used only to explore for additional small cavities which may lie adjacent to the main cavity. Such small cavities may be walled off from the main cavity and connect with it only through minute canals, which are not visible to the naked eye. It is in searching out these cavities that methylene blue is particularly valuable, since it will pass through these hair-like communications, stain the necrotic tissue in the accessory cavities, and enable them to be localized much more readily (Fig. 11-4). If such

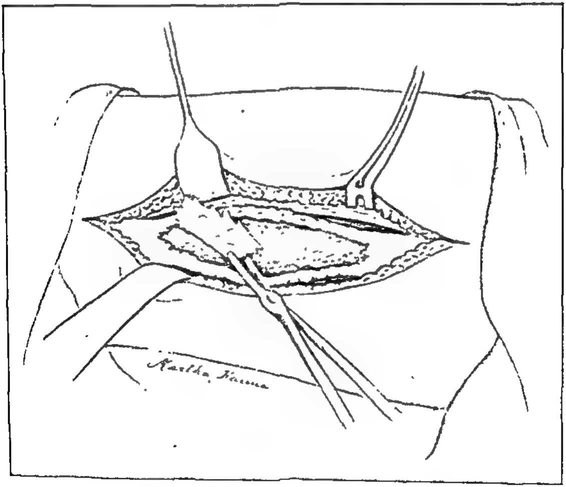

Fig. 11-4. Removal of sequestrum exposed by adequate opening up of infected area of the bone.

small, satellite cavities are overlooked, it is impossible to eliminate the infection, and the operation will be a failure. After all infected material has been removed from the bone focus and a clean, smooth-walled cavity is secured, the walls should be cut away in such a manner as to convert the cavity into a saucerized area in which the walls will slope gently down to the center. An electrically driven burr is helpful in securing a smooth, sloping surface (Fig. 11-5). Such saucerization is necessary if the cavity is to be obliterated by allowing the surrounding soft tissues to fall or grow

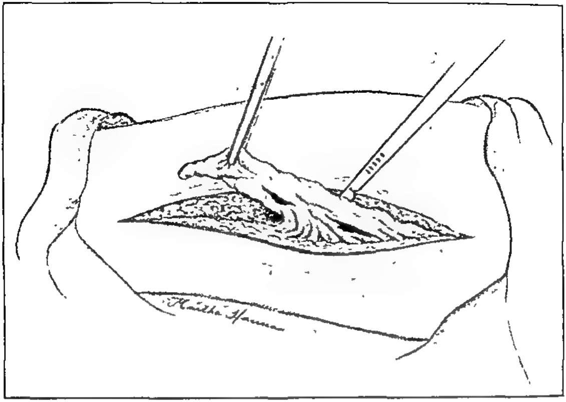

Fig. 11-2. Wide excision of the scar.

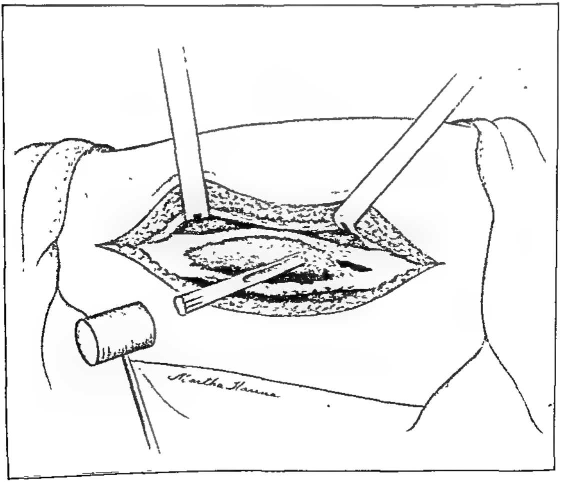

Fig. 11-3. Wide removal of bone to completely expose cavity throughout its extent.

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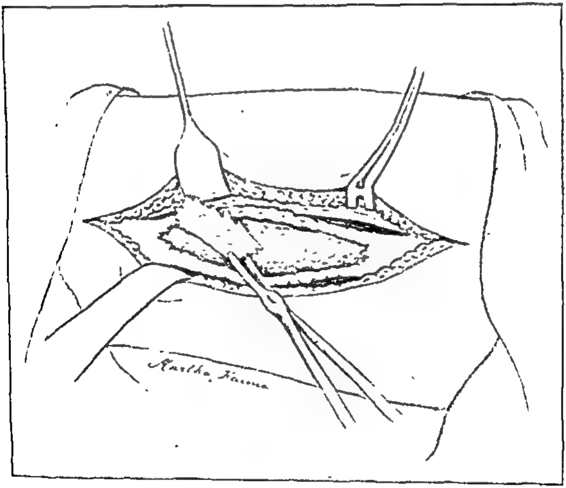

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into the cavity left by the rather extensive removal of bone which is necessary.

After the infected material has been removed and the cavity saucerized, the scar tissue in the adjacent soft parts should be widely dissected away until normal or approximately normal tissue is reached; this is the tissue which must come into contact with the cavity in the bone. Scar tissue does not permit close adhesion between the denuded bone and the surrounding soft parts because it lacks plasticity. In addition it is poorly vascularized and so is unable to supply the lymph flow and circulation which are necessary to bone regeneration. Close adhesion between the soft parts and the denuded bone and as rapid establishment as possible of a blood supply from the surrounding soft parts to the denuded bone are essential to healing.

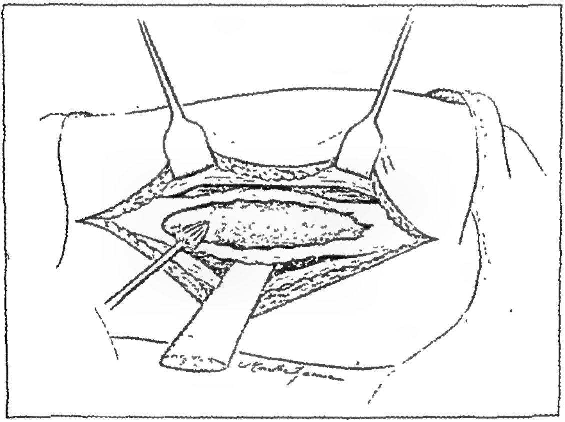

Fig 11-3 Smoothing out the cavity and its edges with an electrically driven burr.

When the clean-up of the focus, saucerization of the cavity, and proper preparation of the soft parts have been completed, the tourniquet should be removed and hemorrhage controlled. At this point a decision must be made as to the manner in which the wound is to be treated until healing occurs.

Broadly speaking, in the past four methods have been employed in the treatment of subacute and chronic osteomyelitis:

1. The conventional method of thorough débridement of the focus or foci, followed by repeated packings of the cavity with some form of material to provide drainage.

2. The maggot method of Baer in which, after thorough débridement of the focus, live maggots were introduced into the cavity. These maggots, acting as scavengers, removed all debris and produced a clean wound, which was allowed to heal by granulation or was closed by secondary suture.

3. The Carrell-Dakin method, which consists in thorough *débridement* of the focus, followed by irrigation of the cavity with Dakin's solution every two hours, day and night, until the wound is free of infecting organisms, as demonstrated by laboratory methods. When the wound is sterile, secondary closure is made.

4. The Orr method in which, following a thorough débridement, the cavity is packed with petrolatum gauze; the region adequately immobilized in plaster and left undisturbed for long periods of time. This formula is followed out until healing is complete, changing casts only when necessary and always at long intervals.

It is not proposed to discuss the relative merits of these four methods of treatment except to state that the first has been largely discarded by those who have had any considerable experience in the treatment of osteomyelitis. The Carrell-Dakin and the Orr methods are those most generally followed today, with the Orr method decidedly leading in popular favor. Both the Carrell-Dakin and the Orr methods have definite disadvantages. The Carrell-Dakin method usually requires a long period of hospitalization and meticulous care in the daily dressings which are necessary. The chief objections to the Orr method are the long period required for healing and the fact that healing is largely by scar tissue; this is a real disadvantage in many locations.

There can be no doubt but that the so-called Orr method has been a most helpful addition to the treatment of subacute and chronic osteomyelitis. In the hands of the average surgeon, it is unquestionably the safest form of after-treatment and gives very satisfactory healing in a high percentage of cases; it should be the method of choice except for those who are willing to take the time to carry out properly the Carrell-Dakin method. The Carrell-Dakin method, on the other hand, unquestionably has the advantage of a shorter healing time and healing with a minimum of scar formation, since secondary closure of the wound is carried out.

The ambition of those interested in the treatment of hematogenous osteomyelitis has been to eliminate completely the disease and if possible to shorten the very prolonged period of treatment required to secure healing by the methods in use. In 1940, impressed with the results reported by Albert Key, following the implantation of sulfanilamide in contaminated wounds, it was determined to try sulfathiazole, administered by mouth and implanted in the wound, in the treatment of subacute and chronic osteomyelitis Sulfathiazole was selected on the basis that it is a more effective agent than sulfanilamide against the staphylococcus, and so should be more effective in the treatment of osteomyelitis, in which 90 per cent of the cases staphylococcus is the infecting organism.

The plan of attack was based on the statement made by Key that powdered sulfanilamide in the wound is similar to a test tube experiment in

which a concentration of the drug of approximately 1,000 mg. is brought into contact with any bacteria which may be present in the media. In such concentration, according to Key, the sulfanilamide is effective against a small number of staphylococci and of Welch bacilli, and against a large number of streptococci. Key, as the result of his work, concluded that when sulfanilamide is implanted in a wound, the drug exerts a neutralizing effect on the toxins present, thus minimizing the amount of tissue breakdown, and that the drug converts bacteria into a static or nonpathogenic phase in which they do not invade the surrounding tissues and do not multiply. In this static state, the bacteria are taken care of by the normal clearing mechanism of the animal and are destroyed. It was felt that if this premise were sound, and it seemed to be, that if a thorough débridement of the sinus and infected bone were carried out in subacute and chronic osteomyelitis, sulfathiazole powder introduced into the wound (Fig. 11-6) should be effective in the same way against the comparatively small number of staphylococci and other contaminating organisms which would remain.

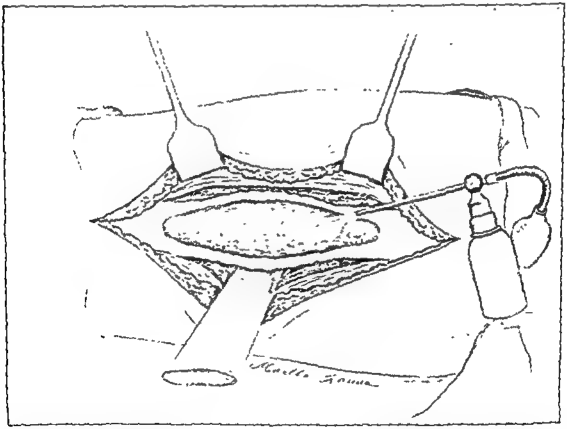

Fig 11-6 Introducing sulfathiazole into the cavity. An insufflator should be used and the raw surface powdered only The drug should not be dusted into the wound as large clumps will form and act as foreign bodies

An additional indication for the use of powdered sulfathiazole locally was the fact that there is considerable evidence to show that pus is a definite depressor on the action of the sulfathiazole group, and that fibrous encapsulation of a focus makes it difficult for the drug to reach the focus through the blood stream in sufficient concentration to be effective. Both of these factors are present to some extent in subacute and chronic osteo-

myelitis; and consequently, the effect to be expected from sulfathiazole administered by mouth alone *would be minimal.*

The plan of treatment was: First, the administration of sulfathiazole (now penicillin or other antibiotics if the sensitivity of the predominant organism has been established) for at least three days before operation in sufficient quantities to assure a satisfactory blood concentration; the purpose of this was to secure whatever benefit possible from the presence of the drug in the blood stream. Second, thorough débridement of the local focus and the introduction of powdered sulfathiazole into the wound. Local treatment was carried out as follows:

1. A tourniquet was applied to the extremity to be operated upon and remained in place until a cast was applied following the operation.

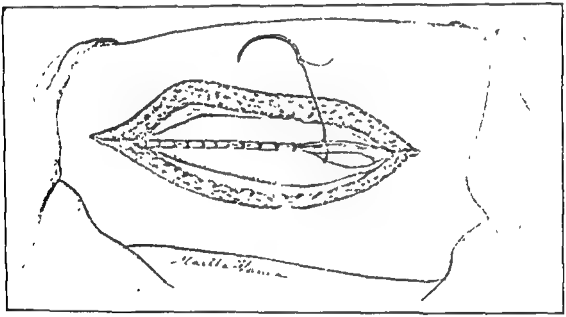

Fig 11-7. Closure of the deep part of the wound by suturing muscle flaps deeply into the saucerized cavity

2. The sinus tract or tracts were injected with methylene blue for the purpose of staining and so outlining all necrotic material in the soft parts and in the bone (Fig. 11-1). The scar was widely excised (Fig. 11-2).

3. The involved part of the bone was freely exposed, and using mallet, chisel, and gouge, all dead and necrotic bone stained by the methylene blue, was removed, and the cavity saucerized as thoroughly as possible (Figs. 11-3 and 11-4). The rough edges which remained were smoothed off by the use of an electric burr (Fig. 11-5).

4. All scar tissue in the soft parts was dissected away as extensively as possible, thus providing healthy tissue which could be brought into contact with the bone cavity when closure was made.

5. One to two grams of sulfathiazole powder was then introduced into the wound, using a nasal insufflator (Fig. 11-6).

6. The deep soft parts were then sutured with interrupted sutures in such a manner as to bring them into as close contact as possible with the denuded area of bone (Fig. 11-7). The skin was closed with cotton

thread (Fig. 11-8). A voluminous firm dressing was applied in such a manner as to press the soft parts as firmly as possible into the bone cavity. Finally, a plaster cast was applied adequately to immobilize the extremity (Fig. 11-9).

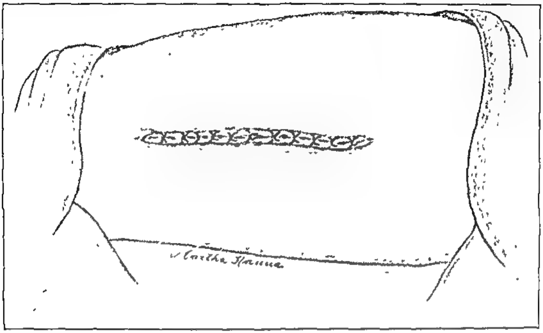

Fig 11-8 Closure of the skin with interrupted cotton sutures.

Fig. 11-9. Snug fitting plaster cast applied to completely immobilize the area operated upon and adjacent joints

In evaluating the effectiveness of these methods of treatment, the cases of subacute and chronic osteomyelitis in this series have been divided into three groups: the first, 0 to 15 years of age; the second, 15 to 30 years; and the third, those over 30 years of age. Tables 11-1, 11-2, and 11-3 show the comparable results.

Table 11-1. Orr Method

Age	Number of Cases	Average Healing Time	Number of Failures	Per Cent of Failures
0 to 15	6	6.0 months	2	33.3
15 to 30	5	15 0 months	0	0
30 plus	2	25 0 months	0	0
TOTAL	13	13.3 months	2	[illegible]

Table 11-2. Carrell-Dakin Method

Age	Number of Cases	Average Healing Time	Number of Failures	Per Cent of Failures
0 to 15	84	2.3 months	5	5.9
15 to 30	53	3.3 months	4	7.5
30 plus	25	6.0 months	5	20
TOTAL	162	3.8 months	14	11.1

Table 11-3. Débridement, Antibiotics and Chemotherapeutic Agents, and Primary Closure

Age	Number of Cases	Average Healing Time	Number of Failures	Per Cent of Failures
0 to 15	45	0.78 months	1	2.2
15 to 30	38	0.85 months	3	7.8
30 plus	21	0.74 months	2	9.5
TOTAL	104	0.79 months	6	5.7

A fair comparison of the results of the Orr treatment with the Carrell-Dakin and chemotherapy methods is not possible, since so few cases were treated by the Orr method. Therefore, the failures will not be discussed.

It is permissible to state, however, that it has been our experience that the healing time in those cases in which the Orr method has been used is quite long, extending over a number of months. It has also been our experience that healing when this method has been used takes place with rather extensive scar formation. This is undersirable, as such scar tissue harbors bacteria which may remain quiescent for years, then because of lowered general resistance or local trauma become active and light up the infection anew.

Healing by the Carrell-Dakin method is on the average much more rapid than in those cases where the petrolatum pack was used, as indicated by the comparison tables. Of almost equal importance is the fact that a secondary closure is carried out, which minimizes the amount of scar tissue; this is an insurance against the probability of future lighting up of the focus.

Healing in those cases in which sulfathiazole or sulfadiazine was used systemically and sulfathiazole locally, and primary closure made, was much more rapid than in those cases in which the petrolatum pack or Dakin's method was used. The short healing period has been constant in our experience over the past seven years, so we feel that the method is well established. Primary healing leaves, of course, the best type of scar, practically the same type of scar as that secured in a clean wound. This method, however, requires a most meticulous cleaning up of the infected bone and extensive removal of scar tissue in the surrounding soft parts. Unless both of these requirements can be met, it should not be used. Long continued suppuration, resulting in the extensive production of eburnated bone and massive scar formation in the surrounding soft tissues so that the cavity in the bone can not be completely blocked with normal muscle tissue is, we believe, a definite contraindication to using this method.

Since the introduction of penicillin, this drug has been used intramuscularly preceding the surgical clean-up of the infected area and for two weeks following surgery instead of sulfathiazole. It is our impression

thread (Fig. 11-8). A voluminous firm dressing was applied in such a manner as to press the soft parts as firmly as possible into the bone cavity. Finally, a plaster cast was applied adequately to immobilize the extremity (Fig. 11-9).

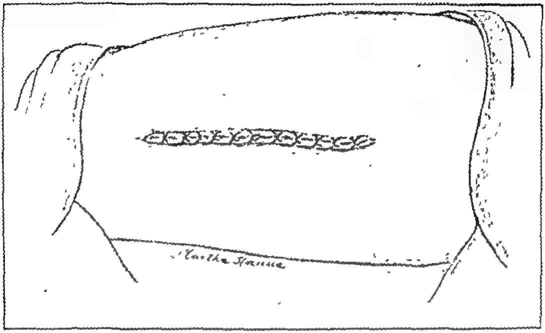

Fig 11-8. Closure of the skin with interrupted cotton sutures.

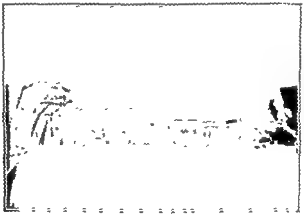

Fig. 11-9. Snug fitting plaster cast applied to completely immobilize the area operated upon and adjacent joints

In evaluating the effectiveness of these methods of treatment, the cases of subacute and chronic osteomyelitis in this series have been divided into *three groups: the first, 0 to 15 years of age, the second, 15 to 30 years;* and the third, those over 30 years of age. Tables 11-1, 11-2, and 11-3 show the comparable results.

Table 11-1. Orr Method

Age	Number of Cases	Average Healing Time	Number of Failures	Per Cent of Failures
0 to 15	6	6.0 months	2	33.3
15 to 30	5	15.0 months	0	0
30 plus	2	25.0 months	0	0
TOTAL	13	*13.3 months*	2	*15.3*

SUMMARY

Hematogenous osteomyelitis is a disease with a definite mortality rate and one which frequently results in a chronic bone infection lasting for years. Early diagnosis and adequate treatment in the acute stage are of paramount importance, both as a lifesaving measure and in the prevention of chronic bone infection. When dealing with a localized bone abscess, early drainage is a sound surgical procedure. In the presence of a septicemia and pyemia, general supportive measures and specific therapy must be relied upon to overcome the disease; surgery has no place in treatment. In the subacute and chronic stages, complete removal of all dead and infected bone by a well planned and thorough surgical operation is demanded if healing is to be secured. No form of systemic or local medication can be effective in the treatment of subacute or chronic osteomyelitis unless adequate surgery has been employed to bring about conditions which enable antibiotics and chemotherapeutic agents to act effectively.

that the results in chronic osteomyelitis have not been better with penicillin given in this way than they were with sulfathiazole, but since penicillin is much less toxic and in acute infection has proved to be much more potent, we have continued to use it in chronic cases.

Sulfathiazole powder is still used locally, as it is still our opinion that its bacteriostatic effect in the wound is an important factor in primary healing. One point should be definitely understood, and that is if local chemotherapy is to be used, the wound must be closed by primary suture and no drainage placed in the wound. If a drain is introduced, the local chemotherapeutic agent is rapidly drained away and accomplishes no worthwhile good, since the effect of local chemotherapy depends upon keeping the agent in contact with the infecting organism for a sufficient length of time to enable it to prevent multiplication of the organisms. Placing the sulfonamides in an open wound, as was done so frequently in World War II, could not be expected to accomplish any useful purpose, the proof of which is that the results were so unsatisfactory that this method of therapy was abolished almost completely.

Irrigating the wound with penicillin after thorough surgical cleanup has been rather extensively carried out, but it seems questionable whether the effectiveness of the penicillin lasts long enough to be effective. Continuous irrigation of the wound with penicillin after surgery is not carrying out the principle of primary closure, and keeping the wound open carries with it the danger of reinfection which is present as long as the skin is not closed.

The results in chronic osteomyelitis are not as unsatisfactory as they are generally considered to be, provided adequate surgery is furnished, proper postoperative care given, and the bacteriostatic drugs, such as penicillin and the sulfonamides, are effectively utilized. It is true that in some cases it may be necessary to do several operations before healing is brought about, but this is unimportant compared with the relief from chronically discharging sinuses and the partial invalidism which results. In 259 chronic cases only 19 or 7.3 per cent failed to heal.

Amputations. The desirability of resorting to amputation for relief must be considered when cure of the osteomyelitis fails and an extremity becomes impaired in usefulness, is a source of constant discomfort, and is a hazard to health and life. Unquestionably, amputation is justified and desirable when all reasonable efforts to clean up the osteomyelitis fail, and the disease jeopardizes life, interferes with useful activity, or the cost of its treatment and care becomes an economic burden beyond the individual's ability to carry. Certainly, useful activity with an artificial limb is to be preferred to total or serious incapacity with an infected draining extremity. Of 259 chronic cases, 10 or 3.8 per cent required amputation for one of the above reasons.

The mortality rate from chronic osteomyelitis is not high. In this series of 259 cases, there were eight deaths, constituting a rate of 3 per cent. Death resulted from such complications as amyloid disease, brain abscess, and septicemia.

formities of the sternum, clavicle and scapula developed. On return to a normal diet, normally developed offspring were produced by the same mothers. These results, of course, question the importance of the tendency as the primary factor.

There is growing evidence, therefore, that extrinsic factors may produce growth deformities at an early embryonic age, which may be manifested in congenital malformation hitherto regarded as characteristic intrinsic gene failure. We have in the past considered congenital absence of the upper end of the femur as an intrinsic inherited primary congenital fault.

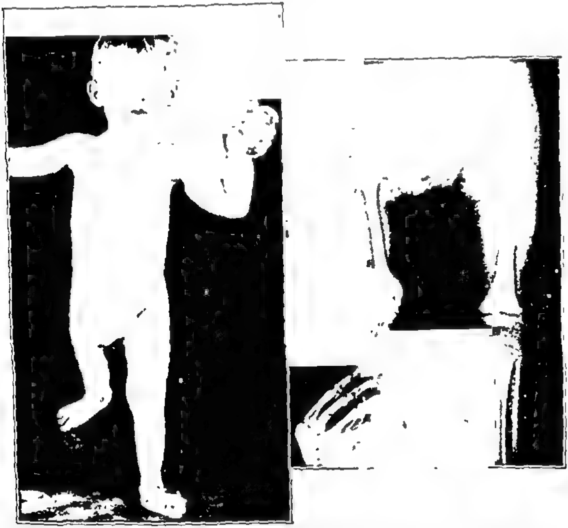

Fig. 12-1 Failure of development of upper end of femur associated with failure of development of fifth ray of the foot Hypoplastic development of the entire caudal limb bud

It seems conceivable, however, that various disturbances regardless of type, occurring at the lower limb bud, as the femur is developing its intrinsic cartilaginous shape, might invariably produce failure of development from the upper portion of the embryonic cartilaginous femur, resulting in loss of ossification and development of the upper third of the femur A damage early to a few embryonic cells may manifest itself late in an extensive deformity (Figs. 12-1 and 12-2). A mild trauma producing a bleb formation damaging a few of the early embryonal cells readily explains this type of deformity, rather than an intrinsic hereditary cause.

There is, however, some evidence that such an accident in early em-

12

DEFORMITIES AND NEOPLASMS OF THE BONE

CARL E. BADGLEY

DEFORMITIES OF THE BONE

Deformities of the bone may be initiated very early in embryonic life, or may develop at any age period throughout life. Insult or trauma of minimal extent in early embryonic life may, by interfering with development at just the right time period, produce a characteristic deformity such as the syndrome of absence or failure of development of the fibula and the outer two rays of the foot, or absence of the tibia, or absence of the upper end of the femur. It is of particular interest that usually the upper end of the femur fails to develop, signifying an interference of growth of the hip system at a specific time in its development.

Jones and Lovett * divided congenital deformities into primary and secondary classes. A primary congenital deformity presumably was produced by inherent defects in the fertilized ovum which influenced the development of the embryo spontaneously without external cause. The secondary congenital deformity was recognized as one which developed after the fetus was normally formed, but as a result of some external cause, or from disease of the fetus itself, deformity developed.

In general, although this has been a very useful classification clinically, genetic proof of inherent factors has been difficult to find. Patten states that geneticists have felt that recessive traits might be carried in the germ plasm of an apparently normal individual until a mating occurred with another person with the same latent defect.

Recent studies in developmental embryology, notably the work of Stockard, have stressed the importance of extrinsic factors rather than hereditary causes for the production of the hitherto classified primary congenital defect. Different disturbances at the same phase of development in Stockard's experiments tended to produce the same defect, whereas the same disturbing factor at different stages of development produced different defects.

Further evidence which tends to remove the stigma of an inherited deformity from this primary congenital defect group has accumulated in nutritional studies as extrinsic rather than intrinsic cause for the defects.

Recently Warkany and Nelson have definitely demonstrated a high incidence of occurrence of skeletal abnormalities in the offspring of hitherto normal rats when reared on a deficiency diet; shortening or absence of the tibia, the fibula, the radius and ulna; fusion of the ribs and various de-

* Jones and Lovett *Orthopedic Surgery*, William Wood, 1923.

formities of the sternum, clavicle and scapula developed. On return to a normal diet, normally developed offspring were produced by the same mothers. These results, of course, question the importance of the tendency as the primary factor.

There is growing evidence, therefore, that extrinsic factors may produce growth deformities at an early embryonic age, which may be manifested in congenital malformation hitherto regarded as characteristic intrinsic gene failure. We have in the past considered congenital absence of the upper end of the femur as an intrinsic inherited primary congenital fault.

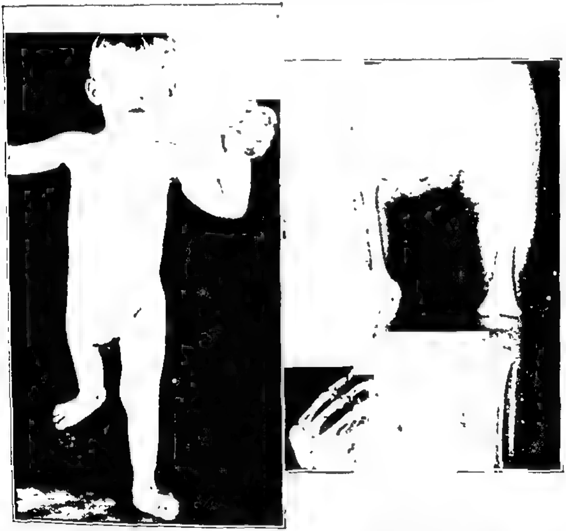

Fig. 12-1. Failure of development of upper end of femur associated with failure of development of fifth ray of the foot. Hypoplastic development of the entire caudal limb bud.

It seems conceivable, however, that various disturbances regardless of type, occurring at the lower limb bud, as the femur is developing its intrinsic cartilaginous shape, might invariably produce failure of development from the upper portion of the embryonic cartilaginous femur, resulting in loss of ossification and development of the upper third of the femur. A damage early to a few embryonic cells may manifest itself late in an extensive deformity (Figs. 12-1 and 12-2). A mild trauma producing a bleb formation damaging a few of the early embryonal cells readily explains this type of deformity, rather than an intrinsic hereditary cause.

There is, however, some evidence that such an accident in early em-

bryonic life may develop a latent intrinsic gene fault which on proper mating with an individual with similar recessive traits might produce intrinsically a similar fault in development.

Fig. 12-2 Roentgenogram demonstrating bilateral absence upper end of femora. Note the abnormal development of the acetabulum

CONGENITAL DEFORMITIES

Congenital bone deformities also have been classified as hypoplastic and hypertrophic anomalies. The more commonly characteristic hypoplastic anomalies may be recorded as absence or defects of the shafts of the long bones. The absence of the fibula frequently associated with absence of the fourth and fifth ray is a fairly constantly appearing deformity. Stunting of growth of the tibia, valgus deformity of the foot, are associated deformities with this lesion. Early ambulation to stimulate bone growth is advisable, utilizing a brace or other external support. Amputation of the leg is sometimes necessary because of the marked calcaneovalgus deformity of the foot. If the deformity is held by a brace, arthrodesis of the ankle

joint, or the so-called triple arthrodesis, may have to be performed when the child is old enough; that is, 7 to 10 years of age.

The absence of the upper end of the femur is another fairly frequent congenital deformity. Here little can be done from a surgical standpoint, except to fit with a prosthesis for function of the extremity to stimulate growth if possible. *Ultimately, reconstruction of the hip and equalization* operations of the limb may have to be considered.

Fig. 12-3. Sprengel's deformity associated with low hair line, a Klippel-Feil syndrome, and a spina bifida occulta in the upper thoracic spine Note the broad short neck and low hair line associated with the high scapula, left.

A third relatively common associated group of deformities is well illustrated in the combination of Sprengel's deformity (Figs 12-3 and 12-4), associated at times with a congenital scoliosis of the upper thoracic spine

Fig 12-4. Roentgenogram of Klippel-Feil syndrome, high scapula associated with absence of the fourth and fifth ribs. This associated deformity we have observed frequently.

and an absence and maldevelopment of a rib, usually third or fourth rib on the left side, with a rather characteristic hypoplastic change in the rib above the absent one.

Congenital deformities of many bizarre types may develop. Absence of the various rays of the hands or feet may develop asymmetrically as is indicated in Figure 12-5, with malformation of the first ray, absence of the second ray and a hypoplastic third ray on the right hand, whereas the left hand shows a total absence of the fifth ray. Polydactylism similarly may occur. Figure 12-6 shows essentially a double foot. Here three extra rays develop which are attached to an enlarged navicular bone. The small recessive toe centrally placed is the big toe, as it has only two phalanges. The surgical treatment of this foot consisted of amputation of the medial accessory three rays.

Fig. 12-5. Failure of development of certain rays in the hands.

Fig. 12-6 Polydactylism Double foot.

Many of these congenital deformities present symmetrical changes with characteristic features which produce a syndrome. Cleidocranial dysostosis is such a deformity characterized by partial or complete absence of the clavicles, associated with a widening of the transverse diameter of the skull and delayed ossification of the fontanelles (Figs. 12-7 and 12-8).

Hypertrophic anomalies may be demonstrated in various lesions, such as an accessory foot, accessory fingers, localized gigantism of the toes, and hemihypertrophy of a limb. The etiology of hypertrophic malformations may be due to an inherited gene for an abnormal growth of the particular part, but it is quite possible that the inherited tendency is on the basis of a fault in proper timing of the system at its period of growth. There is suspicious evidence that partial gigantism is a by-product of abnormalities of the nervous tissues. Several observers, namely Moore and Green, have reported a close relationship between neurofibromatosis and partial gigantism.

Fig. 12-7. Cleidocranial dysostosis Note ability to approximate the shoulders and the widening of the skull transversely.

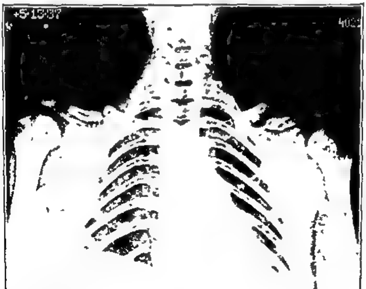

Fig. 12-8. Roentgenograms of immature development of clavicles in a case of cleidocranial dysostosis.

Arthrogryposis Multiplex Congenita. A bizarre type of multiple congenital deformities which is quite akin to a group of similar lesions occurring in sheep, with strong evidence etiologically of genetic intrinsic factors, is seen not infrequently with characteristic changes in the human race. Arthrogryposis multiplex congenita is a term applied by Stern to express the multiple congenital lesions with stiff joints, club feet, club hands, and frequently congenital dislocations of the hips. Previously we have attempted to show that these deformities all may be explained on the basis of a primary muscle dystrophy as suggested by Middleton. We feel that the characteristic position and deformities of the arms and legs are due to fixation of the early fetal position because of failure of rotation of the limb buds due to lack of muscle development. The stiff joints are not inherent, but are normally developed articulations which have lost mobility because of lack of muscle power to produce the usual fetal movements. Motion of joints in utero is important to maintain function of the joint. The club hands and club feet are very probably due to arrest of development and failure of rotation of the feet and hands secondary to the muscle involvement in the extremities. Similarly the dislocations of the hips seen in this syndrome of multiple deformities are at least in part the result of arrested development in early fetal position with loss of muscle power to produce the normal rotation of the limb bud.

Achondroplasia, Fetal Rickets, Chondrodystrophia Fetalis. Achondroplasia is the result of a pathologic process developing in the fetus producing a dystrophy of the epiphysial cartilage demonstrable by a disturbance of normal ossification. The extremities are usually involved. The trunk develops fairly normally, the legs and arms are short. There is an altered rate of growth in the cartilage and bone at the epiphysial disc which produces short bones with some irregularity in joint surfaces so that coxa vara, genu valgum or genu varum may develop.

The treatment is primarily symptomatic. Nothing is known to stimulate normal growth. Deformities can be corrected, usually by osteotomy, at the proper age period, around 10 years, if essential to improve function.

Osteogenesis Imperfecta Congenita. This is another lesion, familial if not definitely hereditary, which is of a congenital origin. Frequently associated with blue sclera and the brittle bones, it has been thought that the lesion was primarily a mesenchymal failure. Fractures may occur in intrauterine life or may occur after birth. As adulthood is reached, fractures are seen less frequently. These cases vary from normal appearing people with occasional fractures with minimal or no trauma, to individuals with marked bone changes, atrophy of the shafts of the long bones, marked bowing of tibia and other bones. Frequently the sclera are china blue in color. The fractures usually heal, although occasionally bone grafts are necessary for union and even then healing occasionally is very slow.

Multiple Cartilaginous Exostoses. These are congenital malformations which are due to a strongly hereditary dysplasia of cartilage, characterized by the formation of multiple exostoses at the long bone ends pointing away from the epiphyses in the long axis of the bone. There are frequently associated changes in development of the metaphysial ends with irregular ossification, widening and ultimately shortening of the involved bone.

Fig. 12-9 Macrodactylism.

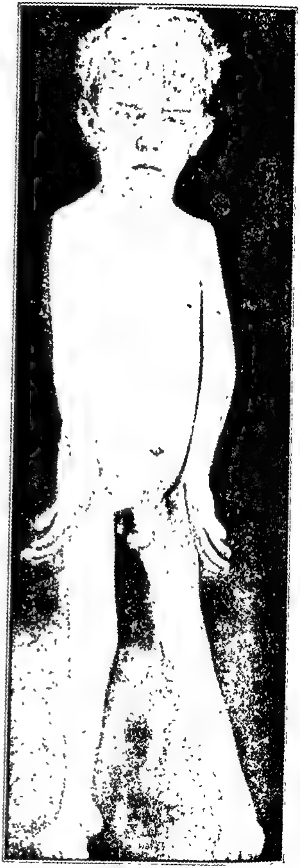

Fig. 12-10 Arthrogryposis multiplex congenita.

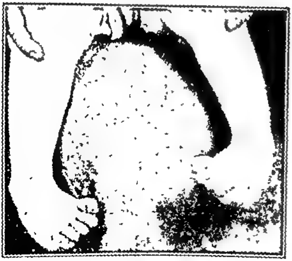

Fig. 12-11 Club feet, bilateral, mild

Treatment of this condition is limited to excision of the exostosis producing symptoms by their size or the bursal irritation covering them. Occasionally malignant degeneration occurs in such an exostosis so that it is wise to remove an exostosis producing symptoms or tending to increase in size. Radical excision including a portion of the cortex of the shaft is advisable.

Other growth disturbances developing in intra-uterine life (Figs. 12-9 and 12-10) as primary intrinsic congenital deformities might be mentioned. These serve as illustrative of lesions probably genetic in origin.

SECONDARY CONGENITAL DEFORMITIES

Growth Changes after the First Three Months of Fetal Life. The secondary congenital deformities, acquired during intra-uterine life, after the fetus has had its normal anlage for development, are best represented by congenital club foot and congenital dislocation of the hip.

Congenital Club Foot. Congenital club foot is a rather broad term which by common usage infers a characteristic deformity of three major components; namely, adduction of the forefoot, varus and inversion of the whole foot, and equinus deformity (Fig. 12-11).

Etiologically, club foot may be the result of primary congenital malformations such as a spina bifida occulta or vara associated with a myelodystrophy which produces an unbalanced foot associated with trophic and sensory changes. Similarly it is present in the multiple deformities of arthrogryposis multiplex congenita, previously mentioned.

In a certain small percentage of males, the club foot seemingly is an inherited trait. In general, however, congenital club foot is the result of a delay in the normal development of a normal foot maintained in an early fetal position.

Correction by first correcting the adduction deformity of the forefoot, secondly the inversion of the foot and lastly the equinus feature of the lesion results, in a high percentage of cases, in permanent recovery. Recurrence of deformity, even after apparently complete clinical correction, occurs frequently enough, that not only must one carefully observe club foot cases for many months but even years to pick up early evidence of recurrence. One must recognize that, either by intrinsic or extrinsic factors, a definite imbalance of muscles persists in some of these recurrent feet, which produces the recurrence. These cases invariably move the forefoot only in the direction of the deformity. Overactivity of the anterior tibial is obviously dynamically present. The peroneus tertius is rarely active and peroneal weakness or mechanical interference of function seems a definite factor.

Roentgenographic studies are of aid in studying the club foot (Figs. 12-12 and 12-13). The anteroposterior view of the midtarsal joints demonstrates the normal Y relationship of the talus and the calcaneus, because of the malposition of the inverted calcaneus disturbing the normal Y relationship. Attempts at correction of the deformity must first achieve proper relationship of the calcaneus to the astragalus as demonstrated by the Kite anteroposterior view. The correction of the equinus element of the de-

Fig 12-9. Macrodactylism.

Fig. 12-11. Club feet, bilateral, mild

Fig. 12-10 Arthrogryposis multiplex congenita.

bones of the leg. The talus is, in untreated club foot, out of its normal position in the relationship to the true ankle joint as well as in improper relationship to the calcaneus.

Slow gradual correction by reapplication of plaster boots, or wedging at intervals, has been a highly successful form of treatment. More recently, a more dynamic spontaneous correction by means of a Denis Browne splint has become popularized. This splint consists chiefly of two simply devised foot pieces to which the feet are firmly strapped. These foot pieces are then attached at increasing external rotation positions to a cross bar. The normal kicking movements of the infant produce an active correcting force for the three components of the club foot deformity.

The recurring foot, or the club foot which does not correct conservatively, may be corrected by soft tissue operations such as Ober's or Brockman's tendon and capsular release procedures.

Ober's operation consists of freeing the medial ligaments from the internal malleolus and the talonavicular joint to the calcaneus.

Brockman's operation consists of:

A. Strip attachment of plantar structures from the under surface of the os calcis.
B. Medial incision exposing posterior tibial tendon. Expose and free astragaloid-scaphoid articulation and medial surface of os calcis.
C. Restoration of the relationship of the talus head to the navicular.

Collapse procedures have been advocated, producing correction by enucleation of bone from the neck of the astragalus, the anterior end of the calcaneus and the cuboid. The primary aim here is to obtain a bone correction without interference of joint function.

If, as sometimes happens, the deformity persists in recurrence after soft tissue operations, then one may be required to consider obliteration of the joint surfaces after correction by triple arthrodesis. Sometimes it is essential, because of overactivity of the anterior tibial, to transplant this tendon to the middle of the foot. We have found the triple arthrodesis, after eight years of age, a very satisfactory operative procedure for persistent recurrent club foot, although it produces a less mobile foot.

Triple arthrodesis consists of:

A. Utility incision between the extensor mechanism and the fibula above the ankle extending down to the fourth metatarsal bone.
B. Exposure through annular ligament to the tarsal sinus, the talonavicular and calcaneus-cuboid joints.
C. Freeing of the capsule of the three articulations enables the foot to be opened like a book by jointly adducting and inverting the foot.
D. The cartilage is then removed from the talonavicular, the calcaneus-cuboid and the talocalcaneal joints.
E. The cartilage and bone removed are cut into fine pieces and placed in the interval between the talus and calcaneus after replacement of these bones. Wound closed and cast applied in correct position.

Congenital Dislocation of Hip. Congenital dislocation of the hip is a bone deformity initiated in uterine life usually as a secondary deformity,

formity is delayed until the normal restoration of the Y, otherwise a rocker foot may be developed due to the inability to dorsiflex at the talonavicular joint. The dorsiflexion develops anteriorly at the base of the metatarsals. Lateral, dynamic roentgenograms are of aid in determining the relationship

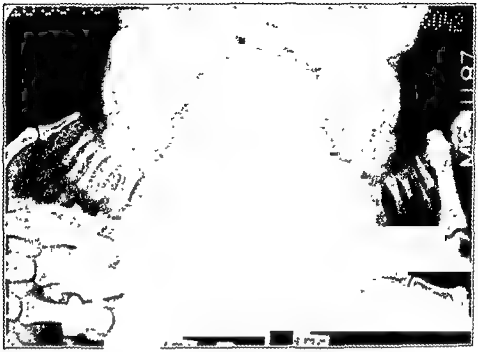

Fig 12-12 Anteroposterior roentgenogram (Kite position to show normal Y relationship of the astragalus and calcaneus on the right, superimposition of these two bones with distortion of the Y on the left).

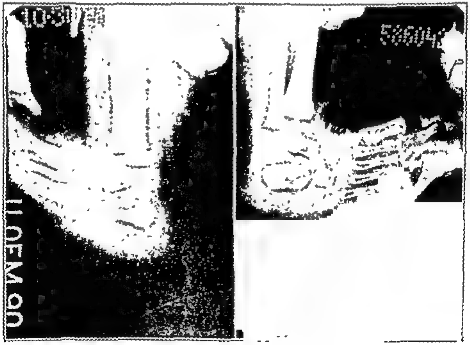

Fig. 12-13. The left shows normal tilting of the talus on dorsiflexion, the right shows parallelism of talus to calcaneus

of the talus to the os calcis Our findings have been similar to Marique, who has pointed out the tendency to parallelism of the under surface of the talus to the superior surface of the os calcis in uncorrected club foot. Also it is important to note the forward position of the ta[illegible]

as the child approximates maturity symptomatology of degenerative hip joint disease is very prone to occur. In fact, in several large follow-up series only 14 per cent, roughly, of reduced dislocated congenital hips maintain normal function in adult life.

With treatment in the first year of life using Putti's triad (1, immature epiphysis; 2, lateral displacement of epiphysis; and 3, acetabular obliquity) as diagnostic signs of dislocation or potential dislocation of the hip, 95 per cent were reported as developing normally after abduction and internal rotation therapy had been instituted. Early recognition and early treatment must be emphasized.

In infancy the diagnosis may be established by the following signs and symptoms:

1. Increase in the number of skin folds of the thigh and asymmetry of the skin folds in contrast to the opposite thigh is suggestive. However, this alone is only suggestive as many cases show asymmetry of skin folds without evidence of dislocation of hip.
2. Increased width of the perineum.
3. Increased prominence of the trochanter laterally, or as frequently occurs, backward displacement of the trochanter are abnormalities suspicious of dislocation.
4. Elevation of the trochanter above Nelaton's line and shortening of the affected limb are suspicious signs but not diagnostic as these changes are found in coxa vara and other conditions.
5. Palpation of the head of the femur. This is diagnostic.
   a. Absence from its usual site in Scarpa's triangle.
   b. Presence of the head laterally or posteriorly.
6. X-ray evidence of the Putti's triad.
   a. Oblique acetabulum.
   b. Lateral position of capitate epiphysis.
   c. Immature development of the epiphysis in comparison with the normal side in a unilateral dislocation.
7. Limitation of abduction, an important and frequent finding.

Posterior dislocation of the hip joint is the more common displacement, but anterior displacement of the head occurs not infrequently. Here the head may be palpated anteriorly with the trochanters usually posterior. Anteversion from 50 to 90 degrees is frequent. Figures 12-14 and 12-15 illustrate a typical bilateral dislocation of the hips, with the lateral view of the pelvis demonstrating the anterior position of the heads of the femurs.

The older the child, the more obvious becomes the diagnosis. The gait is characteristic with a limp produced by the dropping of the pelvis on bearing weight on the affected leg due to the telescoping from loss of stability of the dislocated hip and from gluteus medius shortening. As ossification of the femur matures, the roentgenogram shows more definitely the obvious dislocation.

The treatment for congenital dislocation of the hip varies in accordance with various factors. Age is of particular importance. A. H. Brewster has divided these cases arbitrarily into four groups: group I, from birth until walking begins; group II, from age of walking to three years of age;

but rarely it may be primary, as in the so-called tertatologic dislocations seen in arthrogryposis multiplex congenita.

The etiology of congenital dislocation of the hip of the usual secondary type is not clearly understood. Geneticists have certainly demonstrated a definite inherited tendency, varying in extent from a mild or extreme maldevelopment of the hip joint, the so-called acetabular dysplasia, to the typical congenital dislocation of the hip. In fact, we have demonstrated on numerous occasions that the commonly called acetabular dysplasia is actually due to a displacement of the head outside of the acetabulum with the head pointing anteriorly and the trochanter posteriorly. In several cases diagnosed clinically as acetabular dysplasia, we could not replace the head into the socket without enlarging the acetabulum by removal of capsular tissue. We feel that acetabular dysplasia is definitely a phase of congenital dislocation and is frequently associated with anteversion of the head and neck of the femur. In certain instances it is actually a true dislocation.

Congenital dislocation of the hip is the result, undoubtedly, of factors which produce a definite chronologic break in the usual accurate timing in the relationship of the head of the femur to the developing acetabulum. Embryologically, it is known that the os innominatum and the upper end of the femur are originally one mesodermic mass which, by a cleavage process, ultimately separates to produce the acetabular elements and the head of the femur or component distinct parts of the articulation. Therefore, the hip joint must have had its origin in proper relation and the separation and maldevelopment must have occurred after the cleavage planes have made the two components of the joint separate factors.

We have previously expressed the theory that congenital dislocation of the hip is the result of interference with the normal chronologic development of the acetabulum and the head of the femur during the rotation of limb buds from the original early fetal positions to the attitude characteristic of the human species. Then the head fails to rotate properly into the socket at the correct time, producing a maldevelopment which may only be an acetabular dysplasia of minor nature or may develop into a true dislocation of the hip, usually associated with anteversion of the head and neck of the femur.

The diagnosis of congenital dislocation of the hip should be made in early infancy by simple clinical examination. If the bony nucleus for the upper femoral epiphysis is not developed, as frequently is the case until one year of age, it is difficult without gross displacement to make a definite diagnosis of dislocation of the hip by x-ray evidence. Clinically, however, if one fails to palpate the head of the femur in Scarpa's triangle where it belongs, and does feel it posteriorly or anteriorly lateral to the spine of the ilium, it is obvious dislocation is present.

Early recognition should be simple. We have five patients under six months of age now under treatment. Early treatment is the only hope for satisfactory end results. Reduction of dislocation of the hip is generally successful. Unfortunately, however, in spite of successful reduction, the continued development of the components of the congenital dislocation of the hip rarely catches up with its normal development, and leaves the acetabulum and the head of the femur at variance in size and depth so that

months necessary for complete fixation, followed by slow removal of support and physical therapy without weight bearing for several months.

Group II has a fair prognosis for a permanent good functional result, and an excellent prognosis for an immediate reduction with at least a few years of freedom from limp or symptoms. Delayed changes producing mild acetabular dysplasia, subluxation of the hip, anteversion and even recurrent dislocation will result eventually in a high percentage of cases. The earlier the age of treatment, the lower the percentage of morbidity. Closed reduction usually suffices in this group, but if reduction is not satisfactory, open operation is indicated.

Technic for Open Reduction. Open reduction of the congenital dislocation of the hip is performed as follows:

A. The hip is exposed by the Smith-Petersen approach.
B. The capsule is opened exposing the head and neck of the femur and the acetabulum.
C. The acetabulum is freed of all detritus and the constriction of the capsule opened to allow the head of the femur to enter the acetabulum freely.
D. Usually the leg must be held in some adduction and internal rotation to properly maintain reduction.
E. The amount of anteversion of the head and neck of the femur in relation to the shaft of the femur is computed by the divergence in degrees from the adductor tubercle of the femur. Future osteotomy for anteversion may be required.
F. Wound closed in layers and a plaster cast enclosing both legs and trunk is applied in satisfactory position.

Group III has a much poorer prognosis for ultimately good functional hips, although temporary satisfactory reductions may result. Here again, if possible, conservative treatment, and closed reductions are advised. Sometimes a preliminary period of traction, skeletal preferably, pulling the heads of the femora opposite the acetabulum and then abduction to reduce the adduction contraction is a necessary prelude to closed reduction. An increased number of cases in this group will require operative reduction.

Group IV may have satisfactory reduction under closed or open methods, but the alteration in the development and maturity of the component parts of the hip joint make the chance for a painless usable hip relatively poor as time goes on. The older the case the more prolonged must be the fixation postoperatively.

Older cases and cases which cannot be satisfactorily reduced may be treated by various mechanical methods for production of greater stability, such as shelf operation where bone is laid above the head to support it in its malposition.

Technic of Shelf Operation. In the usual shelf operation it is technically difficult to maintain reduction adequately. The shelf is usually too high above the roof of the acetabulum. We prefer the so-called shelf acetabuloplasty.

A. Hip joint is exposed by the Smith-Petersen approach.
B. After reduction of the head of the femur into the acetabulum leaving

group III, from age of three years up to six years of age; and group IV, from six years of age on.

Fig 12-14. Illustrates a bilateral anterior dislocation of the hips

Fig. 12-15. Lateral view of the pelvis demonstrating the anterior position of the dislocated hips.

Group I may be treated by abduction splint and internal rotation if one is fortunate enough to recognize this lesion early in infancy. Manipulative reduction might well be advisable in the latter months of this period with retention in plaster spica. We have found a minimal period of four

months necessary for complete fixation, followed by slow removal of support and physical therapy without weight bearing for several months.

Group II has a fair prognosis for a permanent good functional result, and an excellent prognosis for an immediate reduction with at least a few years of freedom from limp or symptoms. Delayed changes producing mild acetabular dysplasia, subluxation of the hip, anteversion and even recurrent dislocation will result eventually in a high percentage of cases. The earlier the age of treatment, the lower the percentage of morbidity. Closed reduction usually suffices in this group, but if reduction is not satisfactory, open operation is indicated.

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A. Hip joint is exposed by the Smith-Petersen approach.
B. After reduction of the head of the femur into the acetabulum leaving

the glenoid labrum intact, an osteotomy is made ½ inch above the acetabular margin directly through the ilium into the pelvis.

C. The supra-acetabular bone is then rotated outward and down and held in position by ilial bone graft from the crest of the ilium placed in the interval between the ilium and acetabulum.

Osteotomy of the femur, Schanz or Lorenz type, similarly may be performed.

The Schanz osteotomy, low type, is performed at the level of the ischium. Adduction of the upper fragment, and abduction of the lower fragment is then maintained by a plastic spica doubled.

The Lorenz type of osteotomy consists of cutting the femur obliquely upward and inward just below the level of the acetabulum. Abduction of the lower fragment then displaces the upper end of the distal fragment into or toward the acetabulum.

Arthrodesis of the single hip is not too unfortunate an outcome for these older hips and has been successfully advised and used by several orthopedic surgeons of national fame.

GROWTH DISTURBANCES OCCURRING AFTER BIRTH

Vitamin Deficiencies. Vitamin deficiencies have played an important part in the production of bone deformities. Rachitis (rickets), a vitamin D deficiency disease, and scurvy, a vitamin C deficiency disease, are rapidly disappearing lesions in our better health communities. They still exist with sufficient frequency, however, to emphasize the importance of proper nutrition to maintain proper skeletal growth and to prevent bone deformity. Rickets formerly produced varying deformities, chiefly, however, involving the lower extremities and the spine, such as genu valgum, genu varum, coxa varum, and spinal deformities.

Prevention of these deformities by proper nutrition has been relatively universal in the United States, but still through other illness, carelessness, ignorance or indifference, cases present themselves in an acute or chronic phase of bone deformities.

The surgical treatment of this disease is primarily supportive during the acute phase. Proper splinting or corrective braces may prevent or correct the bone deformities. In the late stages of healed rickets with deformity, surgical osteotomies may be necessary to correct the deformity. It is a good surgical principle to delay operation until the activity of the process has subsided. A good rule is to wait until the patient is four years old. Nonunion may occur, if osteotomy is done through the poorly ossified bone.

Scurvy is primarily a vitamin deficiency disease treated best medically by supplying vitamin C. The orthopedic care consists essentially in supportive treatment only.

Dwarfism. Dwarfism of various types may be considered in this chapter under Bone Deformities, as it is essentially the result of interference of normal growth. There are various types of dwarfism: produced by glandular disturbances; produced by renal disease as in renal rickets; gargoylism associated with hepatosplenomegaly, corneal clouding and mental defect; and

associated with severe visceral disease such as disorders of the pancreas and celiac disease.

Cretinism and its resultant dwarfism is a well known example of hypofunction of the thyroid. In contrast to this type, the symmetrical attractive type of dwarfism called ateleiosis is presumably produced by pituitary involvement. Dwarfism from rickets at an early age, or dwarfism from fetal rickets, achondroplasia, has already been described. Scoliosis at an early age tends to produce dwarfism.

It is of primary importance that we recognize the various factors which can so markedly alter the normal development of our skeletons to the extent of such extensive dwarfism. Bone is a vital organ readily affected and altered in its development by other visceral changes.

Osteochondritis. Localized alterations in bone growth are manifest in analogous lesions appearing in various epiphysial locations, which have been termed osteochondritis. The well recognized Legg-Calvé-Perthes disease of the hip, the Osgood-Schlatter involvement of the tuberosity of the tibia, Scheuermann's osteochondritis of the spine, Freiberg's infarction of the second metatarsal head, Kohler's disc-shaped tarsal navicular, are seen in the growing child. In adults, a somewhat similar type of lesion is recognized in Kienbock's disease of the semilunar bone and Preiser's disease of the scaphoid.

These conditions, described by these various authors originally as an isolated lesion, all have similar characteristic changes which commonly are regarded as the result of an aseptic necrosis to the bony nucleus of the cartilaginous epiphysis. Trauma or infarction has been regarded as the most plausible cause for the asepsis.

The therapy is quite similar for this group in general, mainly protection from weightbearing to prevent collapse and resultant deformity of the cartilaginous anlage for the involved epiphysis.

Hyperextension of the spine throws the weight more on the apophyses than on the vertebral bodies, so frequently it is advisable to use a Taylor back brace for the Scheuermann's cases. Osgood-Schlatter's disease usually responds to relief of patellar tendon pull on the tubercle by the use of a posterior ham splint or a plaster shell to immobilize the leg. Usually two or three weeks is sufficient to relieve the acute symptoms, normal activity can then be resumed. Occasionally, the symptoms are severe and persistent. Rarely, however, is it necessary to hasten ossification by operative exposure and curettement. Kienbock's disease of the semilunar usually requires a carpalectomy. This also is true of Preiser's disease.

Technic of Carpalectomy. A. Dorsal incision medial to Lister's tubercle on the radius. The extensor tendons of the fingers are retracted ulnarward, the extensor of the thumb is retracted radialward.

B. The capsule of the wrist is opened, exposing the navicular and lunate in their combined covering.

C. The lunate lies ulnarward to Lister's tubercle. Freeing its attachments, the lunate is removed.

Danforth has demonstrated the results of prolonged nonweightbearing in Legg-Calvé's disease of the hip. Two or three years of nonweightbearing

are required but the end result of a normal restoration to size and shape of the epiphysis has been achieved in the majority of these cases. Operative treatment to hasten the bony healing of the epiphysis has been proposed by various authors, but the conservative therapy of nonweightbearing is the most acceptable therapy today.

GROWTH CHANGES IN ADOLESCENCE

Epiphysiolysis. Adolescent changes are particularly seen in the adolescent coxa vara or epiphysiolysis which is a deforming factor peculiar to the hip joint. This lesion occurs at the period of adolescence usually between 11 and 16 years of age. It may be divided into two main types: one, the traumatic, an acute slip directly and immediately the result of a traumatic force producing hyperextension of the leg; or, two, the nontraumatic gradual slow displacement of the epiphysis. The latter group of epiphysial slipping properly falls into this chapter of bone deformities representing a type of deformity occurring in growing bone at the adolescent period Four stages for epiphysial slipping have been recognized clinically and roentgenographically: 1, preslip stage; 2, acute slip; 3, chronic slip; and 4, late stage.

1. The **preslip stage** is recognizable by x-ray evidence of increased width of the epiphysial line associated with slight displacement of the epiphysis on a lateral view. This stage when definitely recognized should, in our opinion, be treated by immediate nailing with the Smith-Petersen nail.

Technic. A. Exposure of the origin of the vastus lateralis. Identification of the lateral origin below the trochanter.

B Incise superior attachment of the vastus lateralis back to the posterior margin. Carry incision through to bone along axis of femur 3 inches.

C. Ascertain anterior border of femur and the linea aspera posteriorly.

D. Enter the Smith-Petersen nail or wood screws in direction of center of neck about ¾ inch below superior origin of vastus externus below the trochanter. Check by x-ray both AP and laterally. If in proper direction continue to advance nail or screw through center of the head to about ¼ inch from periphery.

E. Close the wound after roentgen checkup.

This results in early healing of the epiphysial line and prevention of further displacement of the head. When there is no displacement blind nailing is relatively easy and highly successful in maintenance of a normally developing hip.

2. The **acute slip** is either the result of the traumatic type or sudden trauma to the nontraumatic slow slipping type producing an acute displacement which can readily be reduced by traction or gentle manipulation. This group we have successfully treated, usually by skeletal traction by the Russell principle followed after reduction, which is usually readily obtained, by blind nailing with the Smith-Petersen nail, or by the use of wood screws Rarely it is not possible to reduce the acute slip in which case we advise open operation and reduction and internal fixation.

3. The chronic slip stage has been a controversial lesion; most orthopedic surgeons feel that this lesion does poorly by attempts at correction of the deformity. They have advocated prolonged traction. They have advocated subtrochanteric osteotomy to correct the external rotation and the coxa vara. In our clinic we have for years attempted to correct the deformity where it occurs and have aimed our operative treatment in this third stage of chronic slip by correction where the deformity lies; that is, at the junction of the neck and head of the femur. The primary purpose of the operative therapy is to restore the head of the femur properly in position to the neck. Almost invariably in the chronic slip there is new bone formation filling in the gap from the posteriorly displaced head to the anteriorly displaced neck. Then usually it is essential to do an osteotomy, removing a wedge of this new bone formation base anterior so that proper restoration of the head to the neck can be obtained. Occasionally, however, the neck lies so displaced in relation to the head that the axis of the neck is parallel with the transverse diameter of the head. In this case, simple osteotomy and separation of the fragments, freshening of the bone ends and then approximation of the neck to the head can be achieved by turning the head epiphysis forward. Internal fixation by the Smith-Petersen nail or by screw fixation should then be done. Several of the larger clinics such as the New York Orthopaedic Hospital have abandoned this form of therapy, chiefly from fear of the development of aseptic necrosis. This has been a rare complication in our series. Sixty-seven per cent have had a good or excellent end result by this form of therapy. Untreated, or treated by subtrochanteris osteotomy, we have the assured permanent deformity which will almost certainly ultimately produce the degenerative hip joint when the patient passes the fourth decade of life.

4. *The late stage, where the epiphysis has fused in malposition with* resultant bone malformation, is a difficult problem not yet definitely solved. Here a subtrochanteric osteotomy might, temporarily at least, give correction of the external rotation of the leg and correct somewhat the coxa vara.

Technic. A. A circular osteotomy below the trochanter is performed.

B. The external rotation deformity is corrected by internal rotation of the lower fragment the desired degrees.

C. The coxa vara may then be corrected by abduction of the lower fragment, with adduction of the upper fragment at the osteotomy site. Secure fixation by the Jewitt nail, or the contact blade plate can be obtained.

We have tried vitallium cup arthroplasty four times in this group, with relatively poor results It is, however, too early to determine the end result of arthroplasty which is the most desirable aim in the treatment of this phase of the lesion if the function of the hip joint is to be maintained.

Scoliosis. A common bone deformity developing in the adolescent is scoliosis. Scoliosis may, however, appear in any of the formative years.

There are several different types of scoliosis which may be differentiated: one, functional scoliosis, and two, structural scoliosis

One. Functional scoliosis has been defined as a physiologic curvature,

are required but the end result of a normal restoration to size and shape of the epiphysis has been achieved in the majority of these cases. Operative treatment to hasten the bony healing of the epiphysis has been proposed by various authors, but the conservative therapy of nonweightbearing is the most acceptable therapy today.

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2. The **acute slip** is either the result of the traumatic type or sudden trauma to the nontraumatic slow slipping type producing an acute displacement which can readily be reduced by traction or gentle manipulation. This group we have successfully treated, usually by skeletal traction by the Russell principle followed after reduction, which is usually readily obtained, by blind nailing with the Smith-Petersen nail, or by the use of wood screws. Rarely it is not possible to reduce the acute slip in which case we advise open operation and reduction and internal fixation.

ability is the primary curve. The correctable and flexible curves conversely are the secondary curves. The primary curve area is carefully picked out by selecting end vertebrae and apex vertebrae. The end vertebrae are selected in the primary curve as the vertebrae at the end of the curve which are nearest to normal with the pedicles showing the least amount of rotation, and at the area before the rotation begins to change to the opposite for the compensatory curve. The apex vertebrae, on the other hand, show the most rotation of the pedicles and the greatest deformity.

When fusion operative procedures are performed, one must carefully select the fusion area based on the primary curve area. The fusion area encroaches into the compensatory curves to prevent increase of the deformity of the secondary curve from static forces as the result of inadequate fixation of the primary curve.

4. **Paralytic scoliosis** differs in type and in treatment from the idiopathic and should be discussed as a separate entity. The lumbar area is much more frequently the primary curve area. Very commonly there is an associated pelvic obliquity or tilt in response to the primary lumbar curve. The muscle imbalance and the flexibility of the spine from lack of structural vertebral changes characteristic of the idiopathic scoliosis make correction of this type of curve very easy in the early phase of the deformity. The telescoping and weakness of the trunk associated with the muscle imbalance present quite a different problem than the more mathematically precise idiopathic type. One must be extremely cautious in the selection of fusion areas in paralytic scoliosis. We are much more extensive in the selection of the fusion area, and not infrequently feel that fusion from the third thoracic to the sacrum is essential in the marked paralytic scoliosis. Functionally this is not too extensive as the hip joints take up the function of the spine.

5. **Scoliosis from empyema** usually produces a characteristic curve in the thoracic region with the convexity of the curve directed away from the empyema side, probably due to approximation of the ribs to immobilize and collapse that side of the chest.

6. **Scoliosis from thoracoplasty** is an important and frequent complication of this operation. Characteristically, a typical deformity is developed with the apex of the curve presenting the convexity toward the thoracoplasty side.

Prevention of these complications by posture and support is not too satisfactory. It is quite probable that fusion or a temporary fixation of the spine may be a necessity to prevent the extreme deformities in those cases which demonstrate curves not responsive to posture.

Surgery has much to offer in the treatment of scoliosis, but it must be most intelligently utilized or the deformity may become much worse following ill selected fusion areas

AFFECTIONS OF ADULT BONE PRODUCING BONE DEFORMITY

Von Recklinghausen's Disease. Generalized fibrocystic osteitis or von Recklinghausen's disease produces deformity usually through pathologic fracture. A dramatic development of knowledge of the endocrine origin

a type that can readily be assumed and as readily made correctable. Such a type may be produced by a short leg or a pelvic obliquity. This is a physiologic deformity.

Two. Structural scoliosis on the other hand implies a true deformity of the bodies of the vertebra with lateral curvature associated with rotation producing a fixed, uncorrectable deformity, which is not a physiologic deformity, but a pathologic deformity.

The structural scolioses may be subdivided in accordance with etiology into: 1, congenital scoliosis; 2, infantile idiopathic scoliosis; 3, idiopathic scoliosis, adolescent; 4, paralytic scoliosis; 5, scoliosis from empyema, 6, scoliosis from thoracoplasty; and 7, scoliosis associated with muscle imbalance other than poliomyelitis.

1. **Congenital scoliosis** is usually the result of a primary congenital defect frequently associated with other congenital lesions such as Sprengel's deformity, hemivertebra, fusion or absence of ribs, or spina bifida occulta. The recognition of the deformity in early childhood, plus evidence of other congenital malformations, makes the diagnosis of this etiologic type of scoliosis obvious.

The treatment of congenital scoliosis varies considerably in various clinics from extensive removal of the hemivertebra followed by correction and fusion of the spine, to prevent deformity recurring, to extreme conservatism. We favor conservative therapy in this group generally. In our experience the deformity increases in size proportionately to the growth of the child. In such a case, we feel the natural compensatory mechanism for correction above and below the primary deformity should be utilized. If, however, under observation, continued increase in deformity is obvious, correction followed by fusion should be considered. Corrective measures may require operative removal of a hemivertebra, but this certainly should be a most unusual operation.

2. **Infantile idiopathic scoliosis** represents a group of scoliotics under 10 years of age, yet presenting the typical features of a true idiopathic scoliosis of adolescence. We have utilized the term infantile to differentiate these two as we feel from our experience that infantile idiopathic scoliosis is the most deforming type, producing rapid and marked deformity in the unrecognized untreated case and similarly marked deformity in the poorly selected fusion areas in the operated case. The principles of selection of fusion areas are the same for the two, however.

3. **Idiopathic scoliosis of adolescence** usually has characteristic features that enable a definite recognition of the type. The lesion is primarily in the thoracic region with the development of correctable partial or complete secondary curves in the lumbar and cervical areas. Rarely, if ever, is there an obliquity of the pelvis in idiopathic scoliosis, unless there is a secondary associated deformity such as an asymmetrical fifth lumbar. Ferguson particularly has demonstrated methods of selection of the so-called primary and secondary curves based on the fixation of the curves, the structural changes in the bodies, the amount of rotation of the vertebra, associated with the displacement of the pedicles, and the flexibility of the secondary curve.

The curve which presents the least amount of flexibility and correct-

studies have presented figures of as high as 10 per cent incidence of malignant degeneration in Paget's disease. Early amputation if the lesion is located favorably has a fair prognosis in such an event.

Lipoid Granulomatosis of Bone. There are various other lesions producing bone deformity in the adult. Relatively rare metabolic lesions characterized by lipoid changes are grouped under this classification. Lipoid granulomatosis characterized by multiple bone lesions resembling bone cysts or even giant cell tumors without evidence of hyperparathyroidism. The chief histologic characteristics consist of proliferating reticuloendothelial cells with foam cells. Osteitis fibroma disseminata (Albright 1937) and multiple fibrous dysplasia are recently described lesions of a somewhat similar character producing broadening or expansion of bone associated with thinning of the cortex and rarefied appearance of bone to cystic changes. Secondary deformity of bone associated with pathologic fractures may occur.

Gaucher's disease is somewhat akin to lipoid granuloma except that in place of cholesterol, kerasin is the invading lipoid. The most common site of involvement of bone in Gaucher's disease is the lower end of the femur. Enlargement of the shaft, associated with erosion of the cortex without evidence of periostitis or reaction, is noted most commonly roentgenographically. Enlargement of the spleen and liver are concomitant changes. Sternal marrow puncture is essentially negative.

Multiple Myeloma. The term multiple myeloma is closely associated with two names: Bence-Jones who discovered the special protein in the urine, and Kahler whose name is a synonym for multiple myeloma.

This disease of bone is characterized according to Kahler:

1. Deformity and abnormal fragility of the bones.
2. Bone pains.
3. Cachexia.
4. Bence-Jones protein in the urine.

Snapper adds the following findings:

5. Typical x-ray appearance of the bone lesions.
6. Hyperproteinemia, especially globulin.
7. Presence of proliferating myeloma cells in the smears obtained from sternal puncture.

X-ray therapy frequently gives temporary relief of symptoms. Radioactive volts may prove of value in the therapy.

Fracture Deformities. Malunited and ununited fractures and growth disturbances due to traumatic involvement of the epiphysis are a common means of production of bone deformity.

Malunited fractures are the result of failure of treatment to reduce and maintain satisfactory reduction of a fracture until bony healing occurs. It may be the result of the peculiar characteristics of the individual fracture, such as comminution, making it difficult to maintain anatomic alignment. The choice of therapy may be inadequate or through other causes adequate therapy may not be possible to maintain.

of this lesion has occurred since Mandl's operative removal of a parathyroid adenoma in 1926. The lesion is now recognized to be of endocrine origin

Snapper states that the chief characteristic histologic changes are:

1. Proliferation of fibrous tissue in the bone marrow and in the haversian canals. Osteitis fibroma.
2. Cystic changes chiefly cortical produced by bone destruction from hyperactivity of osteoclasts.
3. Decalcification of bone trabeculae.
4. Perforation of thinned trabeculae by proliferating fibrous tissue.
5. New formation of bone.

The skeletal lesions may be extensive and pathologic fractures may occur. Deformity of the spine may be due to bone softening, fish tail vertebrae or pathologic fracture.

The biochemical findings characteristically found in this disease are:

1. Hypercalcemia, usually above 12 mg. per cent.
2. Hypophosphatemia, usually below 2.5 mg. per cent.
3. Hypercalcinuria.
4. Hyperphosphaturia.
5. Increase in phosphatase content of serum.

Roentgen changes of a generalized bone lesion are characterized by:

1. Widening of the marrow spaces.
2. Thinning of the cortex, scalloping or half-moon bone resorption.
3. Diffuse widening of haversian canals.
4. Development of bone cysts or giant cell tumors.

The primary therapy for this lesion is surgical removal of the parathyroid adenoma. The treatment of the bone complications responds well if the adenoma is removed.

Osteitis Deformans. Paget's disease, osteitis deformans, is an affection of adult bone usually occurring after 40 years of age. It is characterized by progressive typical deformities of the long bones and thickening of the skull. Enlargement and increased bowing of the long bones occurs. The etiology is not known.

The chief roentgen characteristics may be summarized briefly:

1. Thickening and broadening of the cortex.
2. Remodeling process and modification of the structures of the cortex.
3. Porosis of bone through loss of calcium.
4. Irregular medullary cavity.
5. Fissures like transverse lines.

The blood alkaline phosphatase is highly elevated in this lesion, sometimes as high as 20 or 30 milligrams per cent.

The surgical treatment for this disease is of minimal importance. Occasionally, if bone pain is severe, as occasionally it is, an extensive guttering operative removal of a segment of the cortex and medulla has been symptomatically beneficial.

Not infrequently fractures occur in this altered bone. As a rule, the usual fracture therapy is generally successful as healing occurs. Various reported

tory aid available. The microscopic diagnosis of the tumor tissue requires an unusually well trained observer, so it is the unusual clinician who alone is qualified. The roentgenologist has acquired a knowledge of characteristic changes seen in the altered bone shadow from which frequently a definite diagnosis can be safely made. On the other hand, many bone tumors show such bizarre and unusual changes, that one cannot rely on an accurate diagnosis by x-ray, although suggestive types of lesions may be considered.

The sedimentation rate is of distinct value. Rarely would one anticipate elevation of the sedimentation rate in benign lesions, but almost invariably it is distinctly elevated in malignant change. The determination of blood phosphatase is also of distinct value, frequently elevated in osteoblastic new growths and, of course, in metastatic carcinoma of the prostate and Paget's disease; it has definite diagnostic value. Blood serum calcium and phosphorus determination are important in certain cases, of distinct value, of course, in hyperparathyroidism. The Kahn or Wassermann serologic test should be routine in all cases. It is recognized that syphilis can portray many variable lesions.

The leukocyte count is also of distinct importance. Certain tumors such as Ewing's sarcoma may resemble acute hematogenous osteomyelitis clinically. The clinical history, the age of the patient, the duration of symptoms, the general appearance of the patient and the local findings are factors of great importance in the primary differentiation of malignancy or benign tumor.

A history of recent injury followed by a gradual increase in symptoms of swelling and pain with evidence of tumor formation certainly favors malignancy. A history of recognized bone enlargement of years' duration suddenly producing pain and swelling and further growth is also strongly suspicious of malignant degeneration.

The age of the patient is important. The primary malignant bone tumors occur most frequently in the first two decades of life. So also, however, do the benign lesions such as bone cysts. The malignant tumor case, however, will have symptoms of pain and swelling and progressive changes, whereas the bone cyst is usually asymptomatic and is frequently accidentally found because of a pathologic fracture. Similarly, the xanthomatosis of bone or other lipid metabolism changes occur in this early age group.

The benign bone tumors can usually be diagnosed clinically by their location, clinical appearance, and the history of development. Roentgen evidence can usually differentiate benign lesions, lesions suspicious of malignant changes, or frank malignant bone changes. The secondary metastatic lesions also often can quite accurately be recognized roentgenographically.

In case of any doubt concerning the nature of a bone tumor, we advocate biopsy. Although in certain lesions biopsy material may be gathered by means of a large special needle, such as the Turkle needle, we favor the surgical biopsy to obtain adequate material for microscopic study. Ordinarily, we do not rely on frozen tissue reports, but wait for the permanently prepared sections for the most accurate observations of the pathology of the submitted tissues.

The biopsy is done under a tourniquet when possible with sufficiently

Occasionally *malunion* seen early enough can be treated by manipulation and freeing of bone ends, and then treatment, as though a fresh fracture, by traction methods may be successful. Frequently, however, open operation and freeing of bone ends by osteotomy is necessary before approximation in satisfactory position can be obtained.

Delayed union is a state in the treatment of the fracture where union has not occurred within the anticipated period of time for a fracture in that bone and locality, but the bone ends do not show evidence roentgenographically of changes opposed to union, and clinically tenderness and swelling and edema persist locally. Delayed union may well eventuate into true bony union if the fragments are protected long enough and stimulated by protected functional use.

Nonunion may be defined as an ununited fracture whose bone ends are so altered that spontaneous union cannot occur. Nonunion is essentially a condition requiring operative therapy to correct the nonunion. A very high percentage of successful results may be obtained by following these simple principles if possible for functional result:

One. Freshen the bone ends to bleeding bone and patent medullary canals.

Two. Approximation and fixation of the fragments preferably by internal fixation.

Three. Dual bone grafts with metal screw fixation, onlay type, are very satisfactory. Reinforcement with a metal plate, if a heavy bone or a very musculatured individual, is a wise precaution.

NEOPLASMS OF THE BONE

Bone tumors present a most difficult clinical problem from a diagnostic and therapeutic standpoint. The great variability of tumor changes as observed microscopically, grossly and by roentgen examination makes a difficult task of classification of bone tumors through definite characteristic findings.

Clinicians, to create some order out of the chaos of the variable nomenclatures for bone tumors, have attempted to accept as a standard classification the one revised and accepted by the Committee of the Bone Sarcoma Registry of the American College of Surgeons. It is possible that in our present clinical state of insufficient knowledge, we are attempting to make too accurate a diagnosis from the microscopic findings.

The first and most important question to ascertain about a bone tumor is whether it is benign or malignant. This question cannot always be accurately answered by microscopic tissue examination alone. However, although there may be considerable disagreement among pathologists as to the type of bone tumor in an individual case, rarely is there much question as to whether the tumor is malignant or benign. This is to be noted in review of the reports of the various pathologists on the sections submitted to them by the Committee of the Bone Sarcoma Registry of the American College of Surgeons.

From a clinical standpoint, the diagnostic problem of bone tumors is complex, requiring an approach from every possible clinical and labora-

One of the most common tumors in children under 10 years of age is the benign cyst (Fig. 12-17) which occurs chiefly in the upper metaphysis of humerus, femur or tibia. In contrast to this location in bone and age group, the giant cell tumor occurs after 18 years of age involving chiefly

Fig. 12-17. Age six years. Bone cyst of humerus. Solitary cyst of right humerus with a pathologic fracture. Spontaneous healing but fracture occurred at a lower level. Cyst was opened, curetted and packed with bone chips. Good healing observed 15 months later.

the lower femoral epiphysis, or the upper tibial epiphysis or the lower radius. Although the bone cyst and the giant cell tumor are closely related, they show definite characteristic differences in age group, location of the lesion in bone, and characteristics of the gross tumor.

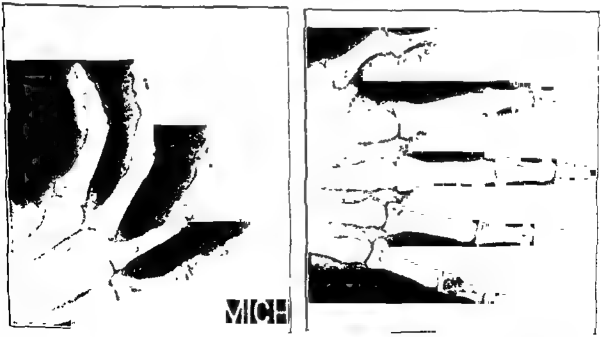

Fig 12-18 Enchondroma of second phalanx of little finger with traumatic fracture following a minor injury

adequate exposure to allow removal of representative tissue. The exposure should be so performed that the incision will not interfere with future plans in the treatment. The wound is closed primarily and the patient immobilized in bed.

The diagnosis and outline of therapy is formulated after a review of all the factors, clinical findings, laboratory reports, roentgen findings and microscopic tissue reports. In the past few years, most large hospitals have recognized the need for close collaboration in the final decision as to diagnosis and therapy and have developed tumor clinics for the purpose of this review. The pathologist, the roentgenologist, and the clinician consider all the factors and agreement as to diagnosis and therapy is established. The case continues to be followed by this group as many years as is possible.

There are a definite group of well recognized bone tumors which have characteristics so that they can readily be classified. The more common benign tumors are:

1. The exostoses.
2. The osteomas (Fig. 12-16).
3. The chondromas (Fig. 12-17).

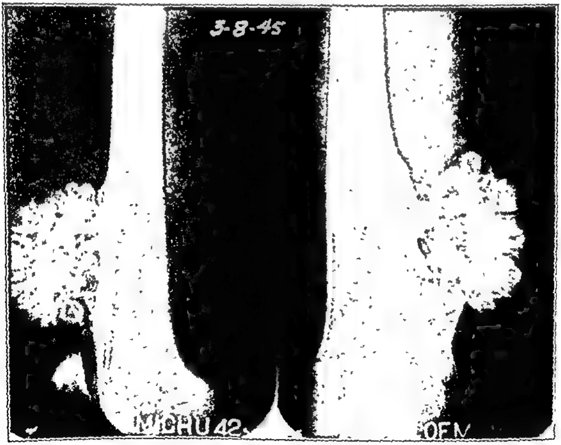

Fig. 12-16. Male Age 25. Typical large pedunculated osteochondroma of the femur Local excision.

These are well differentiated tissues of an adult type and demonstrate a characteristic feature of bone tumors as well as neoplasms of other structures, that the more mature and better differentiated the tumor tissue, the more benign the tumor.

A common type of exostosis is the so-called traction exostosis growing in the direction of the axial alignment of the shaft. These are often bony outgrowths at the ends of the long bones with a narrow or more commonly a sessile base. The free tips are usually cartilaginous and frequently covered by a bursal formation. These tumors are prone to be multiple. Genetically there is evidence of strongly inherited tendencies. If located so as to be exposed to repeated trauma it is advisable to excise the tumor, cutting well into the base into normal bone. Certainly, with any change of size or significant symptomatology, excision is advisable as malignant degeneration does occur.

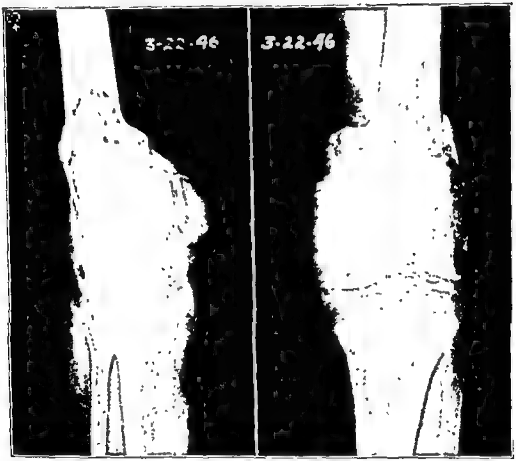

Fig 12-19 (cont.). A year later patient had a pathologic fracture which healed, but progressive changes at site of tumor warranted amputation. Progression of tumor following operation. Not improved by irradiation.

Benign chondromas, chondromyxomas or enchondromas are found frequently in the phalanges and usually first discovered by a pathologic fracture (Fig. 12-18). These may require only conservative care, with annual observation. They respond to surgical therapy if necessary, consisting of a thorough excision or curettage followed by cauterization with 50 per cent zinc chloride. Cancellous grafts may be advisable if extensive curettement is required.

The occurrence of chondroma or myxochondroma in the larger bones is in our experience much more serious. Such a lesion in the shaft of the femur or tibia is potentially dangerous. Malignant degeneration may occur. The myxochondroma is particularly dangerous. Biopsy itself may prove

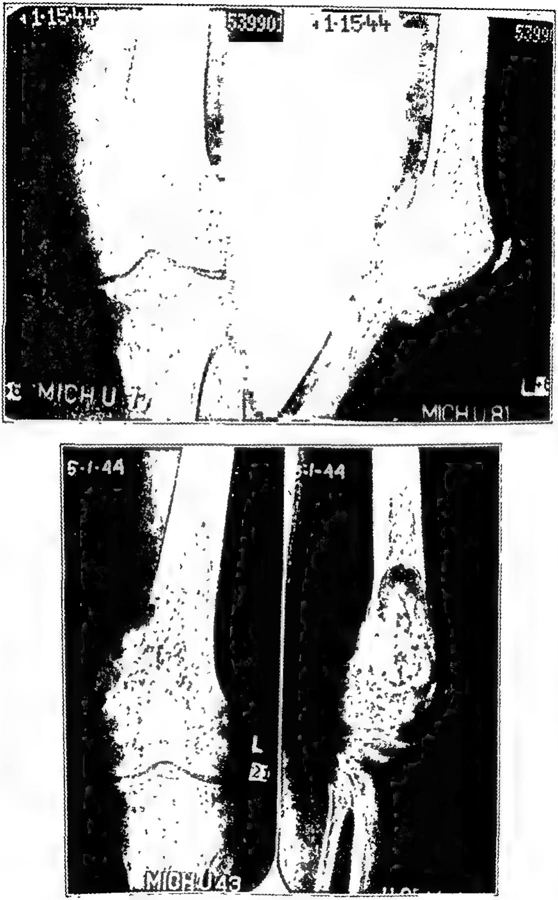

Fig. 12-19. Top, male, age 30 Benign giant cell tumor. Bottom, biopsy followed by curettement and packing with iliac bone. Seven months later, course of x-ray therapy to tumor.

amputation, results in a five-year survival rate of approximately 20 per cent. No other form of therapy has proved as successful, dismal though it be. Amputation has also great value even when the survival rate is relatively short. It alleviates symptomatology, allows resumption of individual activity. Usually the terminal phase is due to pulmonary metastases with symptoms of relatively short duration likened to a pneumonia. Local resection is a gamble possibly successful for a few, but the odds are in favor of amputation if malignancy is proven.

In our reported series of 48 out of 180 cases of osteogenic sarcoma which could be definitely classified, the correlation between the types of osteogenic sarcoma and the periods of survival in the 48 cases are shown in Table 12-1.

Table 12-1. Osteogenic Sarcoma

Type of Lesion	Cases	Average Period of Survival Mos	Five-year Survivals	Percentage of Five-year Survivals
Primary myxochondrosarcoma	11	13	1	9
Secondary chondrosarcoma	14	33	4	29
Sclerosing osteogenic sarcoma	14	48	6	43
Chondroblastic sarcoma	2	16	0	0
Osteolytic osteogenic sarcoma	7	10	0	0

The myxochondrosarcoma is an exceedingly dangerous tumor, in our experience, growing with great rapidity and metastasizing early (Fig. 12-20).

Fig 12-20 Female Age 11 years. Myxochondrosarcoma. Thoracoscap icu-
lation Well nine months later.

to be a stimulating factor in this type of lesion, to be followed by soft tissue invasion by the myxochondroma. One should use the biopsy only if they intend to proceed with a local resection or eradication of the entire tumor by amputation if necessary. Chondroma of the ilium arising from the iliac crest may be readily removed with a portion of the ilium with an excellent prognosis. On the other hand, enchondroma of the ilium enclosing the paracetabular area has a poor prognosis. Ghormley has advocated a hind quarter amputation for these cases because of the high frequency of recurrence and malignant manifestations.

The treatment of the bone cyst is essentially surgical. Exposure of the cystic enlargement of the shaft involved, followed by curettement of the usual lining membrane. It is essential for healing of the cyst to open the medullary canal above and below the cyst. Dense bone formation usually is present separating the cyst from the medullary canal. This interferes with circulation and endosteal bone formation. We favor chemical sterilization with zinc chloride, or phenol, followed by alcohol and then liberally washed with saline. We favor the use of iliac cancellous grafts to fill the cavity as a distinct aid in hastening and assuring complete healing of the cyst. The bone cyst rarely responds to x-ray therapy. Recently by means of a bone bank composed of dry freeze bone sterilized by cobalt 60 radiation, we have had an adequate supply of cancellous bone obtained at autopsy. This may prevent the recurrence of the bone cyst. In the past year we have had an unusually high incidence of recurrence in cysts inadequately filled with autogenous iliac grafts.

The giant cell tumors are benign but present much less well differentiated and more abnormal tissue than is seen in the other benign bone tumors. The true giant cell tumor usually is located in the epiphysial end of a long bone (Fig. 12-19) and makes its appearance after the fusion of the epiphysis and the metaphysis. Diagnosis can be readily made clinically in the characteristic cases with the aid of the roentgenograms. Biopsy of this lesion is advisable, however, because of variants and less benign lesions. There is accumulating evidence of a minority of the giant cell tumors differentiating later into sarcomas with local recurrence associated with metastases to the lungs. X-ray radiation is frequently used in the treatment with fair success. Many months are required, however, for anatomic repair.

Whenever it is practical, we advocate operative exposure, complete curettement of the tumor tissue, chemical treatment by zinc chloride or phenol. We feel the cavity should be filled with cancellous bone. In our experience, one should not combine the operative therapy with the radiation therapy as the grafts may melt away from the effect of the radiation.

THE MALIGNANT BONE TUMORS

The most common primary malignant tumor of bone is the osteogenic sarcoma. Combined with the chondrosarcomas, osteogenic sarcomas form about 50 per cent of the primary bone tumors. These tumors occur chiefly in the young, and more commonly in the males. A history of preceding trauma is found in 40 to 50 per cent of these cases. The lesion occurs most frequently in the femur, next in the tibia. Surgical tre[illegible] chief[illegible]

amputation, results in a five-year survival rate of approximately 20 per cent. No other form of therapy has proved as successful, dismal though it be. Amputation has also great value even when the survival rate is relatively short. It alleviates symptomatology, allows resumption of individual activity. Usually the terminal phase is due to pulmonary metastases with symptoms of relatively short duration likened to a pneumonia. Local resection is a gamble possibly successful for a few, but the odds are in favor of amputation if malignancy is proven.

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15 months, and the number of five-year survivals only two, an incidence of 5 per cent.

Site of the Amputation. It has been a dictum to amputate through the bone above the affected one if possible. Amputation through the bone involved is reserved only for those types of tumor in the lower femur where high amputation can be done more safely than disarticulation. In

Fig. 12-22. Male. Age two and a half years. Ewing's tumor with symptoms of six months duration. Characteristic laminated layers of periosteal reaction. Supracondylar amputation and roentgen therapy. Death six months later.

our series there were 17 patients in whom the amputation was done at a higher level through the involved bone with 5 five-year survivals, a survival rate of 30 per cent. Disarticulation of the hip (Fig. 12-21) was performed in eight patients with a lesion of the femur with no five-year survivals. These, plus 15 others who had amputations through the bone proximal to the involved bone with five-year survivals in 5 (33 per cent), seem to

In a study of 80 cases of osteogenic sarcoma (Badgley and Batts) the following points were suggested:

1. The average period of survival rate under 20 years of age was 21 months, with six five-year survivals or 15 per cent.
2. The average period of survival rate over 20 years of age was 35 months with seven five-year survivals or 23 per cent.

The prognosis is better both for survival rate and five-year survivals in the older group.

The group of cases with the greater duration of symptoms had the better prognosis. Forty-six with symptoms of less than six months had an average period of survival of 20 months and there were eight five-year survivals or 17 per cent. Thirty-four patients had symptoms for more than six months. The average period of survival was 31 months and there were seven five-year survivals or 23 per cent.

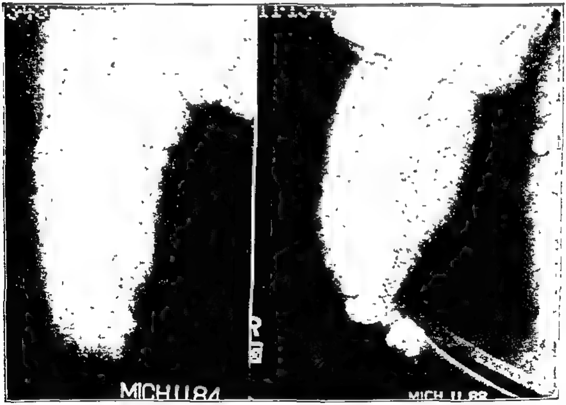

Fig. 12-21. Female. Age 22 months. Malignant tumor of the femur. Primitive hemocytoblastoma consisting of cells of early myeloid type with metastases to regional lymph nodes over femoral vessels in Scarpa's triangle. Hip disarticulation was followed five months later by death from multiple metastases.

The average period of survival of those patients who had metastases on admission was only four months as compared to 29 months for the entire series.

Forty-three patients were treated by amputation, the average period of survival being 42 months, and there were 13 five-year survivals, an incidence of 30 per cent. This was in contrast to the results of 37 patients not treated by amputation, for whom the average period of survival was

15 months, and the number of five-year survivals only two, an incidence of 5 per cent.

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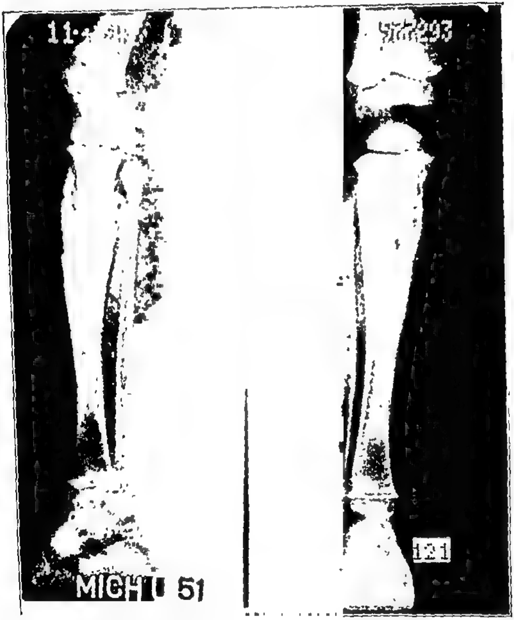

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favor amputation through a normal area in the involved bone, rather than through the bone above. Statistics must be cautiously regarded in bone tumors, but we have felt that in general the plan of attack was essentially to remove all evidence of tumor. This did not necessitate amputation above the joint of the involved bone unless there was evidence of tumor tissue in the remaining portion of the limb.

Periosteal fibrosarcoma is a relatively rare neoplasm of bone presenting two main types, the bone destructive type or the bone reactive type. Twenty-seven of 200 primary malignant bone tumors seen at the University Hospital were diagnosed by Batts on the basis of clinical, operative, roentgen and histologic observations as periosteal fibrosarcoma. This is an unusually high ratio of 1 of every 8 primary malignant bone tumors.

The treatment consisted of either local excision or amputation. Roentgen therapy was a usual adjunct to local excision. The mortality was 50 per cent and the incidence of five-year survival was 40 per cent. All of the patients who survived for five years or more had lesions of a low-grade type of malignancy.

Ewing's sarcoma (Fig. 12-22) is a highly malignant primary bone sarcoma involving chiefly the shaft of long bones, principally in the lower extremity. It may resemble osteomyelitis in its onset with clinical signs of fever, local pain and tenderness and even leukocytosis. There are several characteristic changes noted in roentgenograms such as the onion peel osteoblastic changes involving the metaphysial areas. However, these are *not always present. Coley recommends biopsy before any x-ray therapy* as the tumor is so radiosensitive the biopsy value might be lost through loss of demonstrable tumor tissue.

Radiation therapy should be used in every case as this tumor is the most radiosensitive. Authorities differ but, in general, amputation when feasible is advised, resection if amputation cannot be done, and if neither operative approach is practical, radiation alone.

The prognosis at its best is poor. Coley quotes in a series of 71 cases, 66 failures with five living under five-year survival. Geschichter states a survival rate of about 5 per cent five-year cures following irradiation and amputation or resection.

Malignant bone tumors may be primary in bone, or may be secondary from a primary malignant neoplasm elsewhere. Multiple myeloma is, of course, primary bone malignancy. Secondary metastases in bone occur chiefly with cancer of the prostate, breast, thyroid, lung and kidney. A rather striking characteristic noted by roentgen examination is the maintenance of normal contour of the bone, as a rule, in secondary tumors.

13

SURGICAL APPROACHES TO THE JOINTS

LeRoy C. Abbott, Loren J. Larsen, Ellis W. Jones, Jr., and
Donald B. Lucas, with the collaboration of
John B. deC. M. Saunders

In this chapter the authors have described in detail those surgical approaches to the major joints of the extremities which are commonly used by orthopedic surgeons. As far as space would permit these approaches have been illustrated from anatomic dissections and drawings made at the operating table. For those approaches which are less frequently employed we have sketched their principal points or have merely listed them and appended the readily available references.

In the development of a surgical approach, one of two methods is usually employed. The first method of approach might be termed one which is planned to avoid exposure of vital structures; the second, one which is designed to expose them. In the first, the incision is placed at sufficient distance from vital structures to obviate the necessity of their exposure. This method is to be recommended if adequate exposure of the lesion or lesions can be secured, and if there is only a remote possibility of injury to vital structures. The authors, however, stress the importance of the use of the second method in all instances where access to the site of pathology is desirable, regardless of the proximity of vital structures. In such cases, the exposure of those structures in the path of the dissection, or in the immediate vicinity, is the paramount issue. Failure to observe this fundamental principle, the necessity for exposure, may result in either a permanent loss of function or a surgical disaster.

The operating surgeon should be so familiar with the anatomy that he can plan his own approach, basing it upon the anatomic accessibility of the lesion. This fundamental knowledge of anatomy is of the utmost importance in surgery of the bones and joints. For this reason, in relation to each joint the authors have described the anatomy in considerable detail.

In addition to having an intimate knowledge of anatomy the surgeon who operates upon the joints should employ a rigid aseptic technic and a gentleness in handling the tissues. These are the three prime requisites which offer the greatest assurance of a kindly healing of the wound and minimize the danger of infection. Infection in a joint is always serious for it may lead to irreparable damage to cartilage, bone and supporting structures of the joint, with partial or complete ankylosis.

In the various approaches to the joints, the selection of the proper position of the patient and its maintenance throughout the entire operation is of great importance. The surgeon must work with the part held

and supported in such a way as to provide easy access to the structures which he wishes to expose. He must not be handicapped by faulty position of the patient on the operating table. For example, the supine position in operations upon the shoulder does not provide adequate access to its superior and lateral aspects. Also, the surgeon works in an awkward and uncomfortable position which produces both mental and physical fatigue. These difficulties can be obviated by the use of the sitting position which is described and illustrated in detail on pages 548 and 549.

The incision for exposure of a joint should follow the natural creases in the skin, particularly when it is made on the flexor or extensor surface. For the most part it should be transverse or curvilinear, for such an incision heals with minimal scar tissue. A longitudinal incision is frequently accompanied by extensive scar and the formation of keloid. Both are unsightly and likely to permanently disturb function by restricting the range of motion of the joint.

A valuable aid to the surgeon in the surgery of joints is the pneumatic tourniquet. The authors advocate its use in the surgery of the elbow, wrist, hand, knee, ankle and foot, except where there are positive contraindications such as arteriosclerosis or other conditions indicating defective circulation. In the authors' opinion the criticisms of the tourniquet are due to one of three causes, namely: 1, the selection of the wrong type; 2, faulty application; and 3, the constriction of the blood supply for too long a period of time. The proper type of tourniquet is a pneumatic cuff with automatic control; or in the upper extremity, the blood pressure cuff may be employed. Either one should be applied only after the limb has been emptied of blood by elevation and the application of an Esmarch bandage. The authors use a sterile Esmarch which is applied after sterile drapes have been placed, thus conserving tourniquet time solely for the performance of the operation. Venous congestion of the extremity due to leakage of air from the tourniquet demands the immediate release of pressure and a reapplication. Continued venous congestion causes a bloody field which increases the difficulties of the surgeon. Furthermore, if it is maintained sufficiently long it will produce irreparable damage to soft tissues, particularly the muscles. Continued use of the tourniquet should be limited to from 45 minutes to one hour in the upper extremity; in the lower extremity this time may be extended somewhat, but it has been the authors' practice to release and reapply the pressure in not more than one and one-quarter hours.

The advantages of the tourniquet are that it provides a dry field which facilitates dissection, the delicate handling of tissues and an altogether atraumatic surgical technic The use of the hemostat with damaging and crushing of the tissue is reduced to a minimum. The fine blood vessels which cross the line of incision can first be cauterized and then divided by the Davis-Bovie electric cautery unit, and the cutaneous branches of nerves which are often direct guides to deeper structures can be isolated and preserved. Some of the larger vessels may require ligation, but even here the tourniquet permits clean dissection and the application of the ligatures without the inclusion of soft part tissue.

In operations upon joints where bony surfaces have not been denuded,

it has been our practice to release the tourniquet before the wound is closed. With the employment of careful technic as described above we have seldom found bleeding of any consequence. In certain operations where the surgeon is confident that no large vessels have been divided, for example, in removal of a semilunar cartilage of the knee joint, it has been our preference to remove the tourniquet after the sterile dressings, compression bandage and splint have been applied.

Surgery of the joints calls for scrupulous attention to the details of surgical technic. Preoperatively the skin must be carefully cleansed with soap and water. This should be followed by the application of a non-irritating antiseptic solution. Throughout the operation the skin should be walled off from the wound and must not come in contact with the instruments or the hands of the operator. After completion of the operation the joint should be placed at rest by immobilization in a splint or light plaster for the first few days. Following this initial rest period, function of the joint is maintained by early motion and gradual resumption of weight bearing.

THE SHOULDER JOINT

General Anatomic Considerations. The shoulder is a very complex mechanism consisting of the sternoclavicular, the acromioclavicular and the scapulohumeral joints. Contrary to what has been generally taught, all three joints must move simultaneously in order to produce a complete elevation of the arm. Furthermore, as shown by the work of Inman and Saunders, elevation is accomplished by rotation of the clavicle on its longitudinal axis. This latter movement takes place at the sternoclavicular and the acromioclavicular joints. In an approach to any of the three joints of the complex, the operating surgeon should interfere as little as possible with the ligaments and muscles which support and move them. For example, an arthrodesis for dislocation of the acromioclavicular joint reduces permanently the range of motion of the arm in either the coronal or frontal planes, since limitation in motion in one joint produces limitation of motion in all joints.

THE STERNOCLAVICULAR JOINT

The Sternoclavicular Joint. SURGICAL ANATOMY. The sternoclavicular joint is formed by the sternal end of the clavicle, the lateral part of the superior border of the manubrium sternae and the superior surface of the sternal end of the cartilage of the first rib. The joint is enclosed by a capsule which is reinforced by the anterior and the posterior sternoclavicular ligaments. Two accessory ligaments, the interclavicular and the costoclavicular ligaments, strengthen the joint. The interclavicular ligament blends with the superior portion of the joint capsule on either side and is attached at its center to the suprasternal notch. The costoclavicular ligament binds the inferior surface of the clavicle to the upper surface of the first costal cartilage. The sternoclavicular joint is divided into a medial and a lateral compartment by a disc-shaped meniscus which is attached to the clavicle above, and to the first costal cartilage below, as well as to the capsule in front and behind.

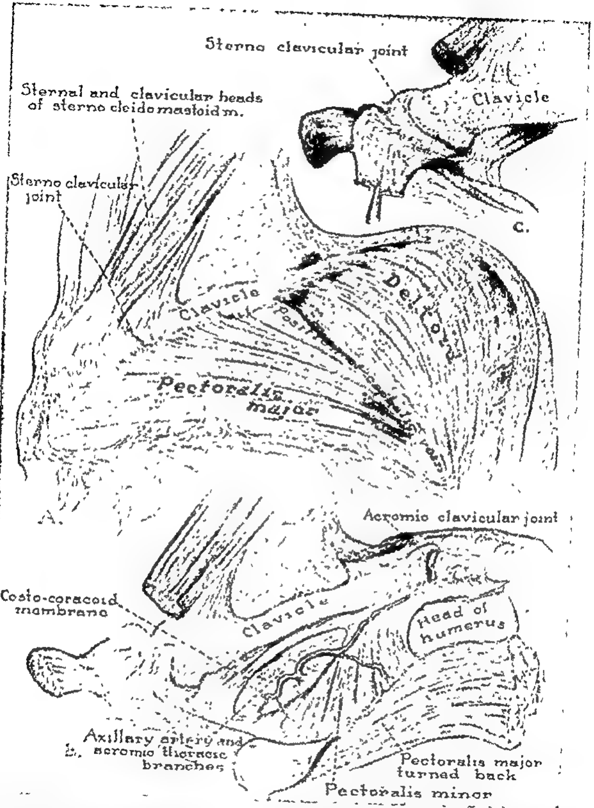


Fig 13-1 Dissections to show anatomic relationships of the sternoclavicular and acromioclavicular joints A, the clavicle and the cephalic vein lying between adjacent borders of the pectoralis major and deltoid muscles The relationship of the sternoclavicular joint to the sternal and clavicular heads of the sternomastoid muscle B, the acromioclavicular joint, the pectoral muscles and the costocoracoid membrane C, the sternoclavicular joint (Courtesy Dr LeRoy C Abbott and associates.)

The important structures on the superoanterior and superoposterior aspects of this joint are respectively the sternal and clavicular heads of the sternocleidomastoid muscle and the sternohyoid and sternothyroid muscles (Fig. 13-1). Directly posterior to the sternoclavicular joint lies the juncture of the subclavian and innominate veins. The anterior jugular vein lies on the medial border of the sternomastoid muscle and passes posteriorly to join the external jugular vein just before it enters into the subclavian.

Surgical Approach to the Sternoclavicular Joint.

1. *Indications.* (a) Recurrent and disabling dislocation of the joint, (b) infection requiring drainage, (c) tumors involving the joint.

2. *Position of the Patient.* The patient is supine with a small sandbag placed between the shoulder blades.

3. *Incision.* A straight or curved incision is made through the skin exposing the capsule of the joint and the two heads of the sternomastoid muscle. The joint surfaces are exposed by curved division of the capsule and by subperiosteal reflection of the heads of the sternocleidomastoid muscle. Through this approach the joint may be thoroughly inspected. When tumors involve this joint, a more extensive dissection may be required with ligation of either the anterior or external jugular veins.

THE ACROMIOCLAVICULAR JOINT

The Acromioclavicular Joint. SURGICAL ANATOMY. The acromioclavicular joint is a diarthrosis between the outer end of the clavicle and the anteromedial margin of the acromion (Fig. 13-1B). The articular surfaces lie in an oblique plane which passes downward and medially. The weak capsule is thickened above and below and contains a wedge-shaped disc which protrudes into the joint cavity from the upper part of the capsule The joint is strengthened by the conoid and trapezoid ligaments which together form the coracoclavicular ligament. This ligament passes from the inferior surface of the outer end of the clavicle to the upper surface of the coracoid, and forms an important structural support to the acromioclavicular joint. The entire upper extremity is swung from this ligament In partial dislocations here, conservative treatment usually yields satisfactory results, but in complete dislocations, surgical repair of the coracoclavicular ligament is often required

Surgical Approach to the Acromioclavicular Joint.

1. *Indications.* (a) Acromioclavicular dislocations, (b) fractures involving joints, (c) infections, (d) arthritis.

2. *Position of the Patient.* The patient is in the sitting position with the shoulder extending well beyond the edge of the table and with the arm at the side.

3. *Incision.* For repair of the coracoclavicular ligament, an extensive exposure is generally required, such as that described by Roberts. Beginning at the angle of the acromion an incision is made over its lateral and anterior margins thence across the acromioclavicular joint, and along the anterior surface of the lateral one third of the clavicle, from here it is turned downward and outward to follow the groove between the pectoralis major and deltoid muscles. Here, the coracoid process is a valuable guide, since

it lies 1 inch below the junction of the middle and lateral thirds of the clavicle and just lateral to this groove, where it is covered by the inner margin of the deltoid muscle. With separation of the pectoralis major and deltoid the cephalic vein is revealed as it passes obliquely upward and backward to pierce the costocoracoid membrane and to join the axillary vein. The vein should be retained within its sheath, and retracted medially with a thin section of the deltoid muscle. The origin of the deltoid is detached from the clavicle with a thin shaving of bone. This produces less bleeding than when a strictly subperiosteal detachment is done. To permit reflection of the origin of the deltoid laterally, the deltoid branches of the acromiothoracic axis are ligated. The coracoid process is then exposed and on it is seen the insertion of the pectoralis minor and the combined origin of the short head of the biceps and the coracobrachialis. Repair of the coracoclavicular ligament may be accomplished by one of a variety of technics such as that used by Bunnell, Bankart or Lowman.

THE SCAPULOHUMERAL JOINT

The Scapulohumeral Joint. Surgical Anatomy. The scapulohumeral joint is formed by the articulation of the large convex surface of the head of the humerus with the comparatively small and slightly concave surface of the glenoid. The glenoid is deepened and enlarged by the labrum glenoidale or glenoid ligament. Above, the joint is strengthened by the so-called arch of the shoulder which is formed by the coracoid, the acromion and the coracoacromial ligament. The capsule, a thin loose structure, is attached proximally to the labrum, except directly above where it is affixed to the bone, while distally it is attached to the anatomic neck of the humerus. The capsule is reinforced anteriorly by the coracohumeral and the glenohumeral ligaments. Active support to the anterior aspect of the joint is afforded by the tendon of the subscapularis muscle which is inserted into the lesser tuberosity of the humerus; to its superior and superoposterior aspects by the supraspinatus, infraspinatus and teres minor muscles which insert in the order named from before backward into the greater tuberosity of the humerus. These four muscles, which form the musculotendinous cuff and the capsule, keep the humeral head in place and maintain the integrity of the joint when the humerus is abducted and the greater tuberosity is levered against the acromion. The capsule of the joint is lined by synovial membrane.

The long head of the biceps muscle arises from the uppermost part of the glenoid margin and traverses the joint to reach the upper end of the bicipital groove. Although this part of the tendon is intracapsular, it is excluded from the joint proper by a layer of synovial membrane. The tendon thus carries a pouch of synovium into the intertubercular sulcus where it is held in place by the transverse humeral ligament which passes from the lesser to the greater tuberosities of the humerus.

The deltoid muscle which covers the shoulder joint must be dealt with in any surgical approach to this joint. A detailed knowledge of its anatomy provides the key whereby access can be gained to underlying structures. The muscle is divided into three parts which function as independent units

(Fig. 13-2). The anterior third arises from the outer third of the clavicle and from the anterior border of the acromion, the middle third, from the lateral border of the acromion; and the posterior third, from the outer two thirds of the spine of the scapula. The three thirds of the muscle fuse distally to insert into the deltoid tubercle of the humerus. The interval between the posterior and middle thirds of the muscle can be split from

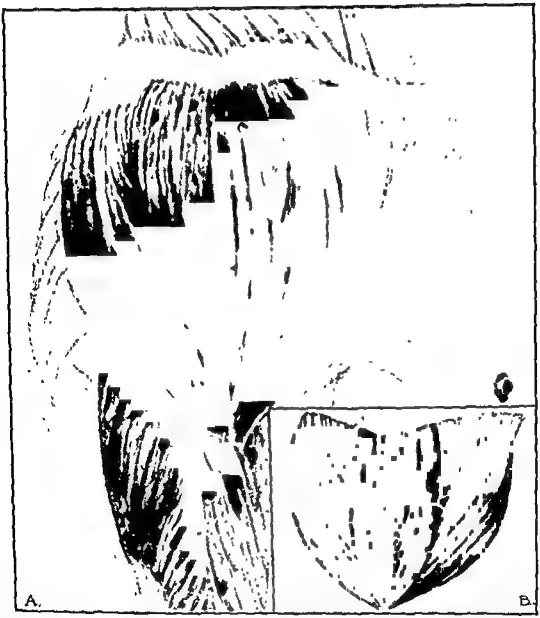


Fig 13-2 A, the tripartite deltoid covering the scapulohumeral joint. B, fiber arrangement of the deltoid muscle as seen from the deep surface (From Abbott, L. C., and Lucas, D. B. Ann. Surg, 136:392, 1952. Courtesy Dr LeRoy C. Abbott and associates)

origin to insertion without endangering the nerve and blood supply to the muscle, since the axillary nerve and posterior humeral circumflex arteries bifurcate before reaching the muscle and thus provide separate branches to the posterior third and anterior two thirds (Fig. 13-3). The interval between the anterior and middle thirds of the muscle is relatively avascular and may likewise be split longitudinally for a distance of about 2 inches distally from the acromion. Utilization of these two intervals permits the

operating surgeon to detach any third of the tripartite deltoid from its origin and turn it down as a U-shaped flap for exposure of structures on the anterior, lateral or posterior aspects of the joint. Reflection of the anterior and middle flaps together permits wide exposure of the joint. Also, since the intervals in the muscle are relatively avascular and fibrous, simple longitudinal splitting without detachment of the origin can be used for limited access to the shoulder joint.

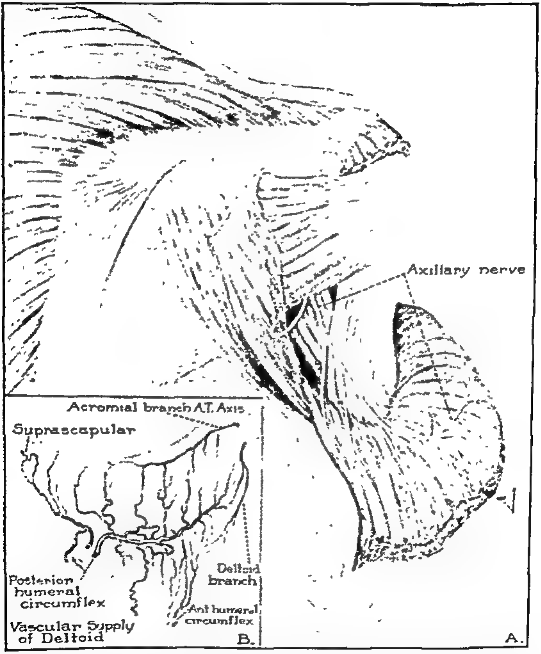


Fig. 13-3. A, the axillary nerve supplying the deltoid, showing its anterior and posterior divisions. B, the blood supply of the deltoid from the posterior humeral circumflex artery and anastomotic branches. (From Abbott. L. C., and Lucas, D. B. Ann. Surg., 136·392, 1952. Courtesy Dr. LeRoy C. Abbott and associates.)

The cephalic vein *lies in the deltopectoral groove which is formed* by the adjoining margins of the deltoid and pectoralis major muscles. Here it is associated with tributaries of the deltoid branch of the acromiothoracic axis. From a superficial position at the lower end of the groove,

the vein passes upward to a deeper level to reach the costocoracoid membrane which it pierces to join the axillary vein. The cephalic vein is, therefore, a useful guide to the axillary vessels.

Beneath the deltoid is the largest bursa in the human body, the subdeltoid bursa. Above, it lies beneath the deltoid muscle, the acromion process, and the coracoacromial ligament; below, it covers the musculotendinous cuff, the tuberosities and the bicipital groove. Codman's book entitled *The Shoulder* contains an excellent description of this important bursa.

The pectoralis major arises from the medial half of the clavicle, the anterior surface of the sternum and the aponeurosis of the external oblique. It inserts through a flat bilaminar tendon into the lateral lip of the bicipital groove. The greater part of the clavicular portion joins the anterior lamina of the common tendon. The full, rounded lower border of the tendon, which is the anterior fold of the axilla, is formed because the fibers take different directions; the superior fibers descend, the intermediate ones track horizontally, and the inferior fibers ascend while passing deeply.

The muscles attaching to the coracoid process are the pectoralis minor, the coracobrachialis and the short head of the biceps. The long head of the biceps arises from the supraglenoid tubercle.

Posteriorly, the tendon of the latissimus dorsi curls around and overlaps the tendon of the teres major as the two pass into their insertions on the medial lip of the bicipital groove. Above them, the subscapularis inserts into the lesser tuberosity.

From behind, the supraspinatus and infraspinatus muscles with the teres minor converge on the greater tuberosity. At the junction of the spine of the scapula and the acromion process, sometimes called the root of the scapular spine, the suprascapular nerve accompanied by the transverse scapular artery winds around under cover of the supraspinatus to enter the infraspinous fossa. The teres minor passes from the posterolateral surface of the scapula to the greater tuberosity of the humerus. The teres major passes forward from the scapular origin to insert on the inner lip of the bicipital groove The two teres muscles are separated by the long head of the triceps which, with the surgical neck of the humerus on the lateral side, forms the boundaries of the quadrilateral space. The axillary nerve and the posterior circumflex artery pass through this space.

Nerves about the Shoulder. The important nerves about the shoulder are both cutaneous and motor The axillary nerve arises from the posterior cord of the brachial plexus under cover of the pectoralis minor, and, after passing through the quadrilateral space, separates into posterior and anterior divisions. The posterior division supplies the motor branches to the teres minor and a few twigs to the posterior part of the deltoid muscle, then terminates by providing sensation for a small area of skin over the upper lateral surface of the deltoid. The anterior division proceeds around the neck of the humerus with the posterior circumflex artery just above the midpoint between the lateral margin of the acromion process and the insertion of the deltoid into the lateral surface of the middle of the shaft of the humerus. It distributes many branches to the deep surface of the deltoid. Protection of this anterior division of the nerve is of greatest im-

operating surgeon to detach any third of the tripartite deltoid from its origin and turn it down as a U-shaped flap for exposure of structures on the anterior, lateral or posterior aspects of the joint. Reflection of the anterior and middle flaps together permits wide exposure of the joint. Also, since the intervals in the muscle are relatively avascular and fibrous, simple longitudinal splitting without detachment of the origin can be used for limited access to the shoulder joint.

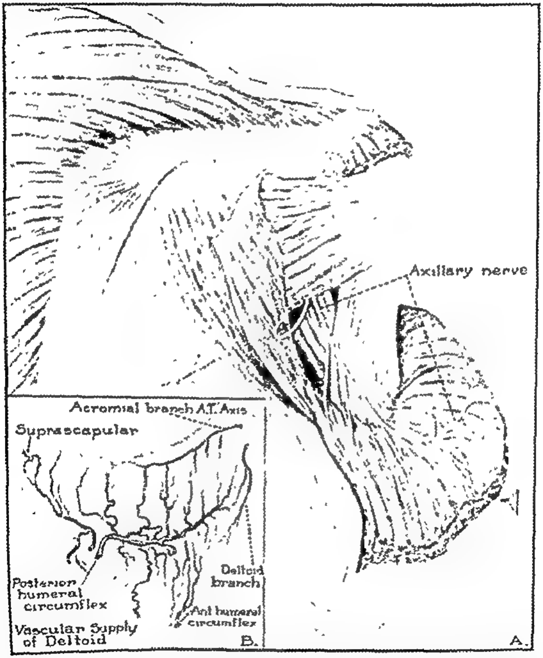


Fig. 13-3. A, the axillary nerve supplying the deltoid, showing its anterior and posterior divisions B, the blood supply of the deltoid from the posterior humeral circumflex artery and anastomotic branches. (From Abbott L C, and Lucas, D B Ann Surg, 136 392, 1952. Courtesy Dr. LeRoy C. Abbott and associates)

The cephalic vein lies in the deltopectoral groove which is formed by the adjoining margins of the deltoid and pectoralis major muscles. Here it is associated with tributaries of the *deltoid branch* of the *acromiothoracic* axis. From a superficial position at the lower end of the groove,

nerves to the teres major, the subscapularis and latissimus dorsi; and the radial nerve to the triceps. All stem directly from the brachial plexus.

ARTERIES. The arteries of importance are the transverse scapular from the thyroid axis, and the branches from the axillary artery, namely, the thoracoacromial and the circumflex humeral arteries. The transverse scapular artery arises from the thyrocervical artery at the base of the neck and passes laterally. We are concerned with it only as it passes through the notch of the scapula where it accompanies the suprascapular nerve into the infraspinous fossa and may be subject to surgical injury. The anterior humeral circumflex artery arises from the axillary artery at the lower border of the subscapularis muscle, and passes behind the origin of the coracobrachialis and the short head of the biceps muscles. It then passes transversely around the surgical neck of the humerus across the bicipital groove, where it gives off ascending and descending branches. The posterior humeral circumflex artery arises from the axillary artery at about the same level as the anterior. It passes backward through the quadrilateral space with the axillary nerve and winds around the surgical neck of the humerus, distributing many branches to the deep surface of the deltoid muscle. The thoracoacromial artery, a short trunk, arises from the second part of the axillary artery and winds around the upper border of the pectoralis minor, where it pierces the costocoracoid membrane and divides into numerous branches. The ramus clavicularis passes upward toward the clavicle. The pectoral ramus is larger and proceeds downward between the two pectoral muscles, anastomosing with the lateral thoracic and the lateral branches of the intercostal arteries. The ramus acromialis runs laterally under the tendon of the pectoralis minor where some of its twigs supply the deltoid. Some twigs anastomose with the transverse scapular and anterior and posterior humeral circumflex arteries. The fourth branch, the deltoid ramus, takes origin from the common trunk, and runs distally in the intermuscular interval between the pectoralis major and the deltoid, supplying twigs to both muscles.

The surgical exposure of the scapulohumeral joint is difficult because of the special anatomic relationship of the structures which surround it on all of its aspects. On the anterior, lateral and posterior surfaces, the joint is clothed by the deltoid. Incisions which pass through this muscle must be made parallel to the direction of its fibers and are limited in their extent due to the position of the axillary nerve as it passes from back to front around the upper shaft of the humerus. On its superior surface the joint is covered by its protective bony and ligamentous arch, made up of the coracoid and acromion processes and the coracoacromial ligament. Full access to this part of the joint generally requires osteotomy of the acromion process together with subperiosteal detachment of the clavicular origin of the deltoid muscle. Exposure of the anterior aspect of the joint is commonly secured by separation of the adjacent margins of the pectoralis major and the deltoid, but in many instances this approach is unsatisfactory unless the origin of the deltoid is separated from the clavicle and adjoining portion of the acromion

The Sitting Position in Operations upon the Shoulder. The authors wish to stress the importance of the correct position of the patient in order

portance to the surgeon in superolateral approaches to the joint. Therefore, incisions which are made with separation of the fibers of the deltoid should not extend downward for more than 1½ inches below the margins of the acromion process (Fig. 13-4).

Fig. 13-4. The sitting position with shoulder projecting well beyond border of operating table. This position greatly facilitates surgical exposure of anterosuperior and superolateral aspects of scapulohumeral joint, the subacromial bursa and musculotendinous cuff. Note position of axillary nerve in relation to incisions which separate fibers of deltoid muscle (Courtesy *Dr.* LeRoy C Abbott and associates.)

Other important nerves in this area are well described in standard textbooks. They are the suprascapular nerve to the supraspinatus and infraspinatus; the musculocutaneous to the biceps and the coracobrachialis and brachialis; the lateral and medial anterior thoracic nerves to the pectoralis major and minor; the upper, middle and lower subscapular

3. *Landmarks.* (a) Outer one third of the clavicle, (b) acromion, (c) coracoid process, (d) deltopectoral groove.

4. *Incision.* An oblique incision is made in the skin along the anterior border of the deltoid from the junction of the middle and outer thirds of the clavicle, downward almost to the insertion of the deltoid muscle (Fig. 13-5A). The margins of the deltopectoral groove are exposed and these two muscles are separated, care being taken to protect the cephalic vein by preserving its fascial covering together with a few fibers of the deltoid muscle. The vein is then retracted medially and numerous tributaries of the cephalic vein and the deltoid division of the thoracoacromial artery are ligated. The deltoid muscle is retracted laterally to show the coracoid process, the deltoid portion of the subacromial bursa which overlies the lesser tuberosity, the anterior portion of the greater tuberosity and the bicipital groove. The bursa is opened to reveal the greater tuberosity of the humerus, the bicipital groove, the tendon of the long head of the biceps, and the anastomosing vessels which arise from the anterior circumflex artery and pass upward and downward in the groove (Fig. 13-5 B and C). By rotation of the humerus, and separation of the long and short heads of the biceps, the lesser tuberosity and the medial lip of the bicipital groove with the insertions of the tendons of the subscapularis, the teres major and the latissimus dorsi are exposed.

This incision may be enlarged above by detachment of the deltoid from the outer third of the clavicle and the anterior margin of the acromion process, or below by subperiosteal separation of the tendinous insertions of the pectoralis major and deltoid muscles into the shaft of the humerus (Fig. 13-5 B and C).

B. Shoulder Strap Incision of Henry.

1 *Indications.* (a) Tumors of the anterior aspect of the joint, (b) fractures involving the joint, (c) arthrodesis of the joint, (d) recurrent dislocation of the shoulder, (e) tenosynovitis or dislocation of the tendon of the long head of the biceps.

2. *Position of the Patient.* The patient is supine with a small flat sand bag under the lower part of the scapula on the side of the operation, or preferably the patient is placed in the sitting position, with the shoulder well over the margin of the table and the arm draped to permit a motion of the joint.

3. *Landmarks.* The landmarks are the same as those used for the deltopectoral incision.

4 *Incision* The anterior part of the skin incision is the same as for the deltopectoral. At the upper end this incision is extended from the tip of the coracoid over the superior aspect of the shoulder to the level of the spine of the scapula. The cephalic vein is retracted medially with a few fibers of the deltoid muscle and the deltopectoral groove is followed to the clavicle to expose the anterior surface of the outer third of this bone and the adjacent margins of the acromion process. With an osteotome the origin of the deltoid is detached with a thin shaving of bone from the anterior margins of the clavicle and the anterior part of the lateral margin of the acromion Care should be taken here not to cut too deeply into the bone This approach very adequately exposes the coracoid process and its

to facilitate operations on this important joint. They have used the sitting position for many years for cases of calcified deposits in the musculotendinous cuff and ruptures of the supraspinatus tendon (Fig. 13-4). More recently they have used it for recurrent dislocation of the shoulder, removal of cervical ribs and for exposure of the brachial plexus in the supraclavicular region. In their experience the preferable position is one with the trunk at approximately 70 degrees with the horizontal plane, the shoulder extended well beyond the margin of the table, the head turned to the opposite side and the sterile drapes arranged to leave the arm entirely free so as to permit motion of the shoulder joint. A tilting operating table which holds the hips and knees in moderate flexion gives the desired slope upward behind the knees, so that the thighs rest against an inclined plane. In this way the patient does not slide downward and out of position. The tilting operating table also permits a quick change in the position of the patient in case of emergency, such as difficulty with the anesthetic. Local anesthesia is particularly suitable for operations upon the shoulder, and the authors have used it extensively in the removal of deposits from the musculotendinous cuff and for repair of rupture of the supraspinatus tendon. Active movement of the arm by the patient during the operation helps materially in exposure of this joint through limited incisions and also aids in diagnosis and in the repair of damaged structures.

SURGICAL APPROACHES TO THE SCAPULOHUMERAL JOINT

I. Approaches to the Anterior Aspect of the Joint
- A. Deltopectoral Incision
- B Shoulder Strap Incision (Henry)
- C. Longitudinal Separation of the Fibers of the Deltoid
- D. Anterior U-shaped Flap

II. Approaches to the Superolateral Aspect of the Joint
- A. Longitudinal Splitting of the Deltoid Fibers
- B. Longitudinal Splitting of the Deltoid Fibers with Partial Separation of the Deltoid from the Margin of the Acromion
- C Transverse Division of the Deltoid Muscle (Gill)
- D. Separation of the Deltoid from Its Origin on the Clavicle and Acromion (Henry and Cubbins)
- E. Osteotomy of the Acromion (Saber-cut Incision of Codman and Transacromial Approaches of McLaughlin and Darrach)
- F. Lateral U-shaped Flap

III. Approaches to the Posterior Aspect of the Joint
- A Approach of Kocher
- B Approach of Harmon
- C Approach of Rowe
- D. Posterior U-shaped Flap

IV. Approaches to the Inferior Aspect of the Joint
- A Approach along the Posterior Fold of the Axilla
- B. Axillary Incisions for Drainage of Pus in the Axilla

I. Approaches to the Anterior Aspect of the Joint.

A. Deltopectoral Incision.

1. *Indications.* (a) Fractures and dislocations of the shoulder, (b) tenosynovitis and dislocation of the long head of the biceps.

2. *Position of the Patient.* The patient is supine with the arm at the side, or supported in varying degrees of abduction by an armboard.

attached structures, the large subacromial bursa, the bicipital groove, and the tendons inserting into the greater tuberosity. Upon incision into the bursa, these bony structures and their tendinous insertions are readily viewed. Further bony elevation of the origin of the deltoid may be continued completely around the lateral and posterior margins of the acromion and adjacent spine of the scapula to give complete exposure of the superior aspect of the shoulder joint.

Exposure of the deeper aspects of the shoulder joint including the anterior margin of the glenoid is obtained by osteotomy of the coracoid process. Furthermore, by incising the fascia over the interval between the inferior margin of the pectoralis minor and the medial border of the combined head of origin of the coracobrachialis and biceps muscles, the axillary artery and veins and the cords of the brachial plexus are identified. It is not usually necessary, however, to expose these structures in order to osteotomize the coracoid process. This can be accomplished by incision of the periosteum on its superior aspect and subperiosteal reflection of the structures attached to it.

After osteotomy of the coracoid process, the tip of the bone, with the origin of the coracobrachialis and biceps thus preserved, is turned medially and inferiorly. The fascia covering the subscapularis is divided at the junction of its tendon and muscle belly which is about an inch medial to its insertion into the lesser tuberosity of the humerus. The tendon of this muscle is then separated in a medial direction from the underlying capsule until the anterior rim of the glenoid is exposed.

In recurrent dislocation, the tearing of the capsule from the labrum or the detachment of the labrum itself can be identified and repaired. Repair is aided by a specially designed retractor which pushes the head of the humerus laterally and posteriorly and by instruments which permit drilling of the anterior margin of the glenoid process.

Closure of the wound is accomplished by suturing or nailing the tip of the coracoid to the base of the coracoid process, or preferably by subperiosteal excision of the tip and suture of the origin of the coracobrachialis and the short head of the biceps to the base of the coracoid. The deltoid is turned back to its normal position and sutured to the clavicle and acromion. Henry advocates resuture by a single loop suture around the clavicle. For postoperative care he suggests immobilization by sling or Velpeau bandage, the arm being maintained at the side. The period of immobilization depends upon the nature of the injury.

C. Longitudinal Separation of the Fibers of the Deltoid.

1 *Indications.* (a) Calcified deposits in the subacromial bursa, (b) rupture of the musculotendinous cuff, (c) fracture of the tuberosities, (d) tenosynovitis of the long head of the biceps, (e) recurrent dislocation of the long head of the biceps.

2 *Position of the Patient* The patient is in a sitting position with the arm free at the side and the shoulder over the margin of the back rest. The elbow is held at a right angle with the forearm supinated.

3 *Landmarks* (a) Acromioclavicular joint, (b) acromion, (c) humerus, (d) bicipital groove.

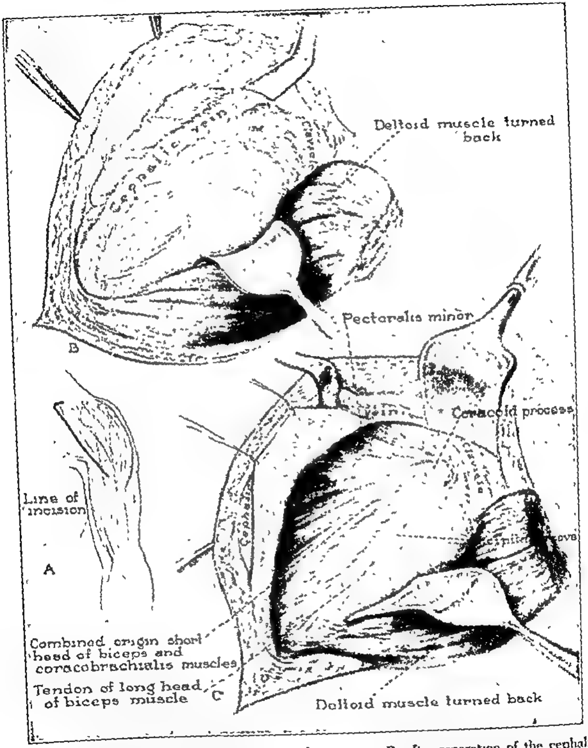


Fig. 13-5. The deltopectoral approach A, skin incision B, after separation of the cephalic vein from the anterior margin of the deltoid, the clavicular origin of this muscle is detached subperiosteally and retracted laterally C, fascia over the pectoralis minor is incised and retracted medially to protect the cephalic vein and expose the coracoid process The tendon of the long head of the biceps is seen in the bicipital groove (Courtesy Dr LeRoy C. Abbott and associates.)

at the top of the incision over the margin of the acromion (Fig. 13-6). With opening of the bursa and with voluntary movement of the arm, the insertion of the musculotendinous cuff into the tuberosities, the bicipital groove, and the anastomosing branches of the suprascapular and circumflex vessels are exposed. The musculotendinous cuff can be seen as far back as the insertion of the teres minor, although this is sometimes difficult. Therefore, for complete rupture of the supraspinatus and for evacuation of calcified deposits in the posterior aspect of the cuff a similar incision is used but is placed farther laterally.

D. Anterior U-shaped Flap.

1. *Indications.* (a) Fractures of the head, neck and tuberosities of the humerus, (b) extensive rupture of the rotator cuff, (c) tenosynovitis and dislocation of the tendon of the long head of the biceps, (d) recurrent dislocation of the scapulohumeral joint, (e) complete dislocation of the acromioclavicular joint.

2. *Position of the Patient.* The sitting position is employed.

3. *Landmarks.* (a) Coracoid process which is covered by the anterior portion of the deltoid muscle, (b) outer half of the clavicle, (c) acromioclavicular joint, (d) apex of the acromion, (e) angle of the acromion formed by the junction of the lateral border of the acromion and the inferior border of the spine of the scapula.

4. *Incision.* An inverted U-shaped incision is begun 1 inch below and 1 inch medial to the tip of the coracoid process. From here it passes directly upward to a point 1 inch above the middle third of the clavicle, where it turns outward to parallel this bone and the posterior margin of the acromioclavicular joint. It bisects the lateral border of the acromion process and then turns downward to follow the direction of the fibers of the deltoid for a distance of 2 inches below the apex of the acromion (Fig. 13-7). Through the inner arm of the U-shaped incision, the superficial infraclavicular triangle is exposed. It is formed by the middle third of the clavicle, the anterior margin of the deltoid and the upper border of the clavicular head of the pectoralis major. Lying deeply between the muscles, the cephalic vein is revealed as it passes through the costocoracoid membrane. It is retracted medially with the protection of its sheath and a few fibers of the deltoid muscle. In the lateral limb of the U-shaped incision, just below the apex of the acromion, is identified the fibrous raphe separating the anterior and middle thirds of the deltoid. It is not as clearly defined as the raphe joining the middle and posterior thirds of the muscle because the path is not straight backward. It pursues an oblique course in a posterior and lateral direction. Thus its deeper portion is overlapped by the anterior fibers of the middle third of the deltoid muscle. This fibrous raphe permits a separation of the anterior and middle thirds of the muscle in a downward direction for a distance of from 1½ inches to 2 inches. Beyond this point, the dissection should not be carried because of the danger of injury to the trunk of the axillary nerve. The periosteum is now incised over the superior surfaces of the outer third of the clavicle and the acromion The acromioclavicular joint and its ligaments are not disturbed. By subperiosteal reflection, the anterior third of the deltoid is freed from its bony origin. As it is turned downward, numer-

4. *Anesthesia.* Local. One per cent novocain with adrenalin is preferable except in cases where muscle spasm is marked and the patient is unable to relax. In such cases the authors have usually used sodium pentothal.

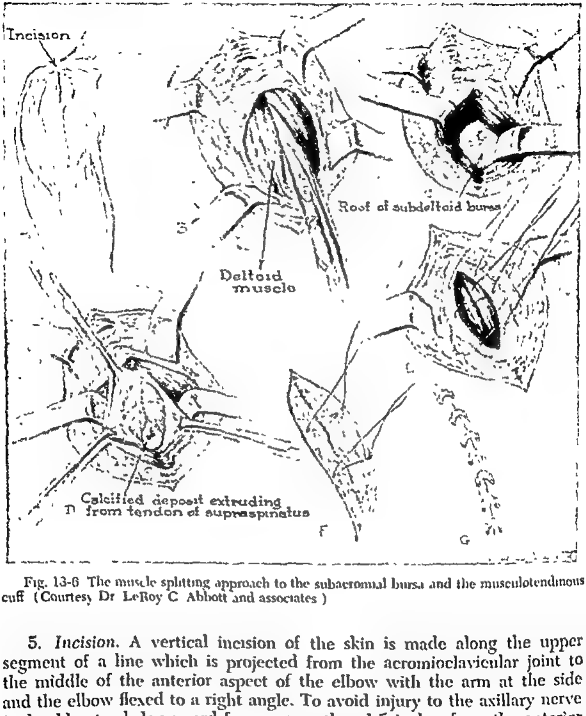


Fig. 13-6 The muscle splitting approach to the subacromial bursa and the musculotendinous cuff (Courtesy Dr LeRoy C Abbott and associates)

5. *Incision.* A vertical incision of the skin is made along the upper segment of a line which is projected from the acromioclavicular joint to the middle of the anterior aspect of the elbow with the arm at the side and the elbow flexed to a right angle. To avoid injury to the axillary nerve it should extend downward for no more than 1.5 inches from the anterior margin of the acromioclavicular joint. The fascia covering the deltoid is split, and its fibers which interlace in a bipenniform fashion are separated and retracted with a self-retaining retractor. In performing this step the authors have found the improved Davis-Bovie unit very useful for coagulation of the small vessels as they cross the field of separation of the muscle fibers. A dry field is thus maintained with minimum damage to tissues. The roof of the subdeltoid bursa is seen but not divided through until the deltoid fibers are separated throughout the length of the wound particularly

first, of division of the coracoid process with reflection downward of the combined origin of the biceps and coracobrachialis muscles; second, the subscapularis muscle is divided at the junction of its tendon and muscle

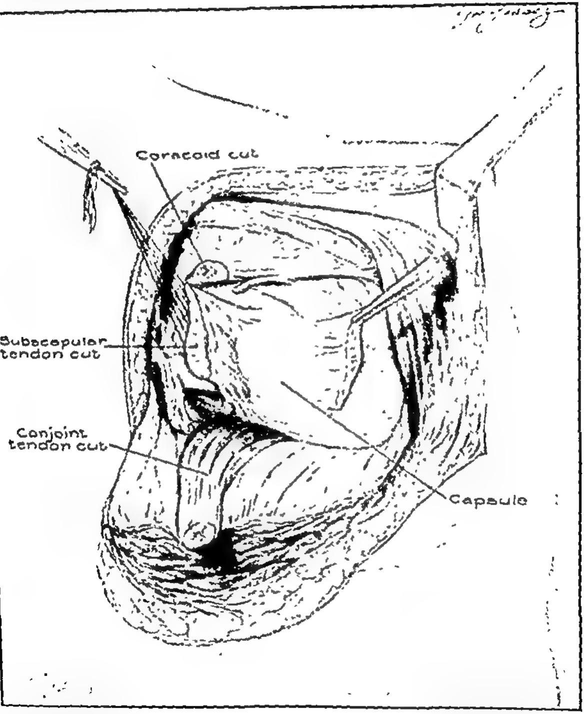


Fig 13-8 Coracoid process severed, and subscapularis divided at its musculotendinous junction to expose the underlying capsule of the shoulder joint. (Courtesy Dr. LeRoy C. Abbott and associates.)

fibers, thus revealing the capsule of the joint (Fig. 13-8). This structure is then incised to expose the anterior rim of the glenoid and the labrum (Fig. 13-9A). In the illustrated case the capsule has been detached from the neck of the scapula, a lesion frequently seen in recurrent dislocation of

ous tributaries from the deltoid branch of the thoracoacromial axis require ligation. The skin muscle flap freed above at its lateral margins is retracted downward, giving an excellent exposure of the underlying structures (Fig. 13-7). These structures are the coracoid process, the coracoacromial and coracohumeral ligaments, the combined origin of the short head of the biceps and coracobrachialis and the insertion of the pectoralis minor muscles.

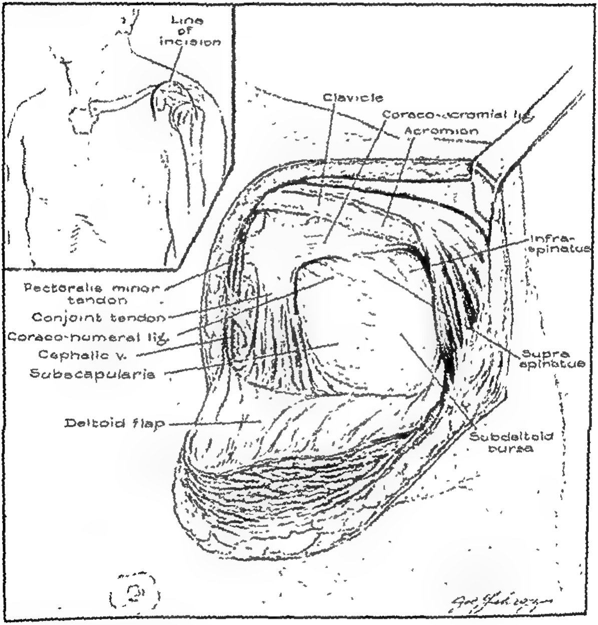


Fig. 13-7. Inverted U-shaped incision and skin muscle flap of the anterior aspect of the shoulder (Courtesy Dr LeRoy C Abbott and associates)

In dealing with fractures of the tuberosities and fractures of the neck of the humerus and ruptures of the rotator cuff, complete exposure of these parts can be secured by freeing the base of the subacromial bursa and turning it laterally. In recurrent dislocation of the shoulder, access to the deeper structures is obtained by two additional steps. These steps consist

first, of division of the coracoid process with reflection downward of the combined origin of the biceps and coracobrachialis muscles; second, the subscapularis muscle is divided at the junction of its tendon and muscle

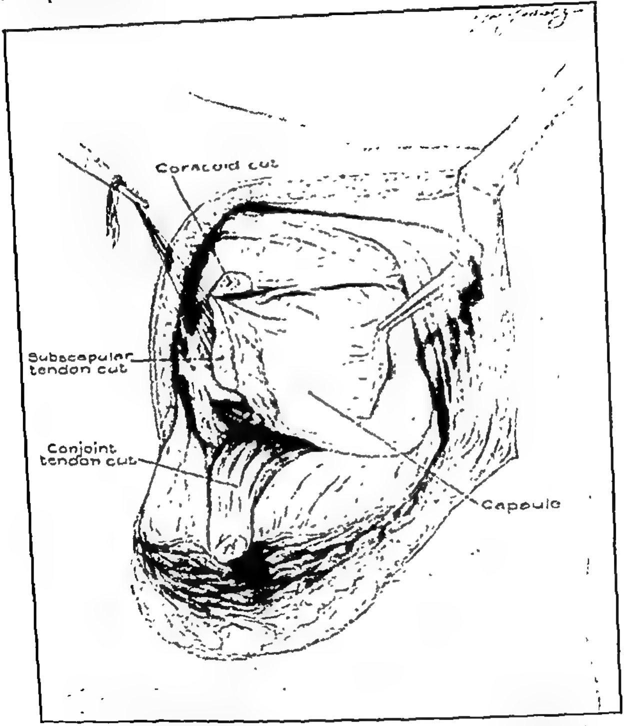


Fig. 13-8 Coracoid process severed, and subscapularis divided at its musculotendinous junction to expose the underlying capsule of the shoulder joint (Courtesy Dr LeRoy C Abbott and associates.)

fibers, thus revealing the capsule of the joint (Fig. 13-8). This structure is then incised to expose the anterior rim of the glenoid and the labrum (Fig. 13-9A). In the illustrated case the capsule has been detached from the neck of the scapula, a lesion frequently seen in recurrent dislocation of

the shoulder. To repair this defect the capsule is reapproximated to the roughened neck with stainless steel tacks (Fig. 13-9B). The arm is then internally rotated and the stump of the subscapularis tendon sutured to the capsule, forming the first layer of the double-breasted repair (Fig. 13-9C). This repair is completed when the subscapularis muscle is advanced and sutured to the underlying tendon (Fig. 13-10).

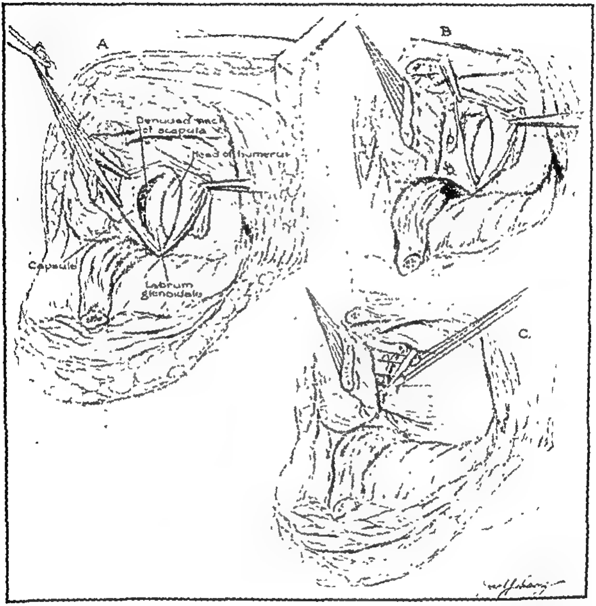


Fig 13-9 A, incision through anterior capsule showing glenohumeral joint and detachment of capsule from scapular neck in recurrent dislocation of shoulder B, capsule reattached to scapular neck with stainless steel tacks C subscapularis tendon sutured to capsule (Courtesy Dr. LeRoy C. Abbott and associates)

After reattachment of the conjoined tendon to the coracoid process the wound is closed by suture of the deltoid to the periosteum on the upper surfaces of the clavicle and the acromion. The adjacent margins of the anterior and middle segments of the deltoid are approximated by suture of the fibrous raphe joining these parts of the muscle. The skin is closed in the usual manner and a Velpeau bandage is applied for support.

II. Approaches to the Superolateral Aspect of the Joint.

A. Longitudinal Splitting of the Deltoid Fibers.

B. Longitudinal Splitting of the Deltoid Fibers with Partial Separation of the Deltoid from the Margin of the Acromion.

1. *Indications.* (a) Removal of calcified deposits which lie in the musculotendinous cuff, (b) for repair of complete rupture of the supraspinatus and extensive tears of the cuff.

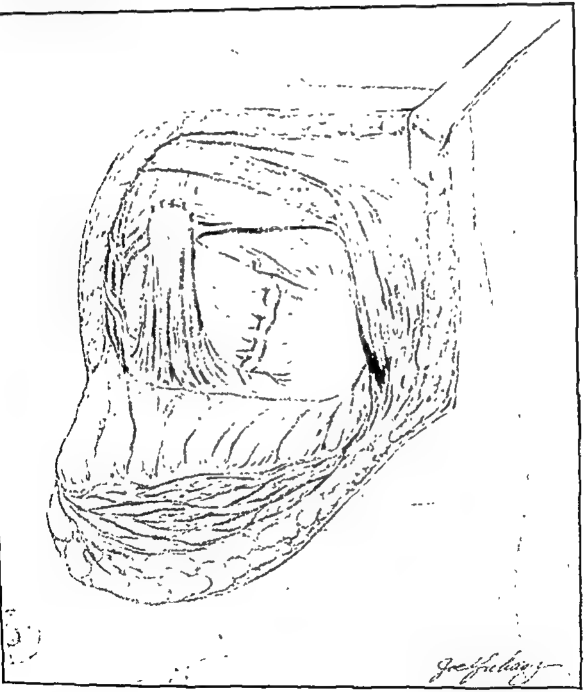


Fig 13-10. The subscapularis muscle is advanced and sutured to its tendon. The conjoined tendon is reattached to the coracoid process (Courtesy Dr. LeRoy C. Abbott and associates.)

2, 3 and 4. *Position. Landmarks. Incisions.* The position of the patient and the landmarks and incisions are the same as for the anterior muscle splitting incision except that the incisions are placed over the superolateral aspect of the shoulder. They begin on the superior surface of the acromion

process and extend downward over its lateral border and upper part of the deltoid muscle. The separation of the fibers of the muscle must not extend further downward than from an inch to an inch and a half below the lateral border of the acromion because of the danger of injury to the axillary nerve. By subperiosteal removal of the deltoid origin from the acromion at the margins of the incision the authors have repaired both partial and complete ruptures of the supraspinatus. In the former, however, removal of irregular projection of scar tissue, bone and the stub of tendon attached to the greater tuberosity will permit of smooth passage of this latter structure beneath the acromion and relieve symptoms.

C. Transverse Division of the Deltoid Muscle (Gill).

1. *Indication.* Arthrodesis of the shoulder joint.

2. *Position of the Patient.* The patient may be in either the supine or the sitting position.

3. *Incision.* The incision has two components. The horizontal portion passes around the shoulder from front to back one-half inch below the lateral margin of the acromion. The vertical arm, beginning in the horizontal incision over the greater tuberosity of the humerus extends downward 2 inches. Two flaps of skin and subcutaneous tissue are thus formed A deep incision is then made through the deltoid at the tip of the lateral margin of the acromion. The capsule is opened and freely excised to gain exposure of the joint. The long head of the biceps, identified anteriorly, is separated from the groove. The acromion process is denuded of all soft tissues on its inferior and superior surfaces and fusion may then be accomplished by removal of the joint cartilage and mortising the acromion into the tuberosity of the humerus.

D. *Separation of the Deltoid from Its Origin on the Clavicle and Acromion* (Henry and Cubbins).

This approach is similar to Henry's shoulder strap incision already described. A superolateral incision is begun anteriorly and curved around the margin of the acromion to the root of the spine of the scapula and the deltoid is separated from its origin on the clavicle and acromion. This approach gives an excellent view of the anterosuperior and superolateral aspects of the joint, and may be used for fractures, arthrodesis of the shoulder joint and repair of the musculotendinous cuff.

E. Osteotomy of the Acromion Process (Saber-cut Incision of Codman and Transacromial Approaches of McLaughlin and Darrach).

1. Saber-cut incision of Codman.

a. *Indications.* (1) Repair of the musculotendinous cuff, (2) recurrent dislocation of the shoulder, (3) fixation of the tendon of the long head of the biceps muscle in the bicipital groove, (4) repair of fractures in the region of the greater and lesser tuberosities.

b. *Position of the Patient* The patient is supine with the entire shoulder exposed laterally and posteriorly and the arm free, or preferably the patient is placed in the sitting position.

c. *Incision.* The incision begins anteriorly 1 inch below the level of the acromion process, and passes directly upward over the acromioclavicular joint and then down the back of the shoulder to 1 inch below the spine of the scapula. The fibers of the deltoid are separated anteriorly and pos-

teriorly from above downward, and the ligaments of the acromioclavicular joint are severed. The acromion process is divided by an osteotome, the division extending backward from the joint to a point medial to the angle of the acromion. The divided acromion and attached deltoid are turned downward and retracted laterally to expose the subacromial bursa, the capsule of the shoulder joint and the insertion of the muscles which form the musculotendinous cuff. This retraction should be done with care to avoid possible injury to the suprascapular nerve and transverse scapular artery which pass through the suprascapular notch.

The tendon of the long head of the biceps is exposed and if the capsule is opened, the head of the humerus and the anteroposterior margin of the glenoid are brought into view.

The objection to this approach as described by Codman is that there is a delay of postoperative movement. The authors also have had two cases in which there was nonunion of the acromion process, and second operations were necessary. As in all deltoid splitting incisions, care must be used to avoid injury to the axillary nerve.

2. The transacromial approach of Darrach and McLaughlin.

The following approach as described by Darrach and McLaughlin is preferable to the Codman approach because the acromioclavicular joint is preserved. The incision parallels the strap or suspender line in the normal skin creases of the region lateral to the acromioclavicular joint. It extends from the posterior aspect of this joint to a point 2 inches in front of the anterior border of the acromion. Anteriorly the bursa and the coraco-acromial ligament are exposed by separating the fibers of the deltoid muscle. McLaughlin emphasizes the importance of splitting the fibers of the deltoid from above downward beginning at the margin of the acromion, for in this way no unnecessary splitting is done and there is less danger of injury to the circumflex vessels and the axillary nerve.

Exposure of the shoulder joint is then obtained by osteotomy of the acromion in a line midway between the acromioclavicular joint and the lateral border of the acromion. The deltoid is retracted laterally with the outer fragments of bone. For repair of the musculotendinous cuff, a more oblique osteotomy, deviating laterally to emerge at the lateral lip of the acromion, gives adequate exposure and a better cosmetic result. The interior of the shoulder joint may be inspected by incisions through the musculotendinous cuff between the margin of the glenoid and the anatomic neck of the humerus.

McLaughlin prefers this approach to others for many reasons. In fractures, bone fragments can be removed without being dragged through the brachial plexus. Repair of the labrum glenoidale and the anterior capsule in recurrent dislocation is carried out from within the joint, avoiding the trauma of sectioning the coracoid and its attachments as well as dividing the subscapularis tendon. The removal of the fragment of the acromion also makes a less prominent fulcrum for impingement of the greater tuberosity in recurring dislocations of the shoulder. The Nicola transplant of the biceps tendon, reduction and fixation of fractures, and reconstructive procedures on the musculotendinous cuff readily can be performed through this exposure.

F. Lateral U-shaped Flap.

1. *Indications.* (a) Avulsion fractures of the greater tuberosity of the humerus, (b) rupture of the musculotendinous cuff.

2. *Position of the Patient.* The sitting position is employed.

3. *Landmarks.* (a) Apex of the acromion, (b) angle of the acromion.

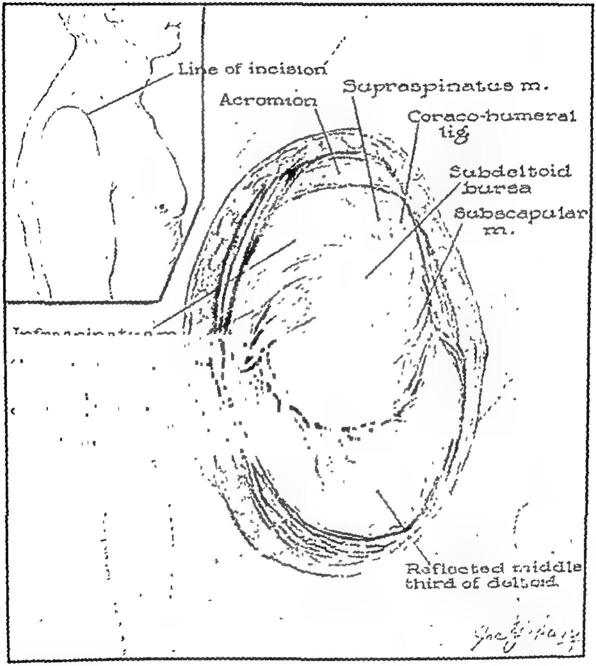


Fig 13-11. Lateral U-shaped incision and skin muscle flap. (Courtesy Dr. LeRoy C Abbott and associates)

4. *Incision.* An inverted U-shaped incision is made over the two avascular intervals of the deltoid and the superior aspect of the acromion. The middle third of the deltoid is separated from the anterior and posterior segments of this muscle by dissection in the avascular intervals, care being taken to identify and preserve the axillary nerve (Fig 13-11). The skin muscle flap is freed and turned downward by osteotomy of the outer margin of the acromion process. Excellent exposure of the musculotendinous cuff

and the tuberosities of the humerus is gained. For complete exposure of the axillary nerve, this structure can be traced into the quadrilateral space allowing inspection of the anterior and posterior branches. Closure is effected by a purse-string suture passing through the upper part of the deltoid and horizontally through a drill hole in the acromion process.

III. Approaches to the Posterior Aspect of the Joint.

A. Approach of Kocher

1. *Indications* (a) Posterior dislocation of the head of the humerus, (b) certain fractures of the head of the humerus and posterior part of the glenoid, (c) excision of the shoulder joint, (d) tumors of the neck of the scapula.

2. *Position of the Patient* As recommended by Kocher, the patient is placed prone with his arm abducted on an arm board and pillows under the chest on the side of the operation with the head turned to the opposite side. An alternate position which the authors prefer is the sitting position with the shoulder well over the side of the table and the arm free.

3. *Landmarks*. (a) Acromioclavicular joint, (b) acromion process, (c) spine of the scapula, (d) posterior border of the deltoid.

4. *Incision*. The incision begins at the acromioclavicular joint and extends backward along the outer border of the acromion to the spine of the scapula. It is then curved downward ending two fingers' breadth above the posterior fold of the axilla The superior and posterior ligaments of the acromioclavicular joint are divided and the trapezius is separated from the spine of the scapula. Through the descending limb of the incision, the dense fascia over the posterior border of the deltoid is divided.

The deltoid origin is then freed from the scapular spine as far laterally as the posterior margin of the acromion leaving a margin of tissue on the bone for resuturing. By detaching the upper border of the infraspinatus, an interval is developed so that the finger can be passed around the root of the acromion. Here the suprascapular nerve and the transverse scapular artery must be carefully isolated and protected. The acromion is then osteotomized obliquely and the outer segment is retracted with the deltoid. As an alternative to division of the bone the deltoid is separated from the spine of the scapula and the acromion as far forward as the acromioclavicular joint. Lifting this deltoid curtain readily reveals the head of the humerus and the muscles inserting into the greater tuberosity. The capsule is now divided over the very top of the humeral head. The tendon of the long head of the biceps is freed from its groove and retracted forward.

The external rotators are divided, leaving enough tendon attached to bone for suturing and the muscles are then drawn backward. The anterior capsule should be left intact even though in some cases it may be necessary to detach the insertion of the subscapularis. The integrity of the anterior capsule limits the tendency of the head of the humerus to displace upward and inward toward the coracoid process. By this method a wide exposure of the head of the humerus is obtained without impairment of function of the deltoid

B. Posterior Approach of Harmon.

Incision The incision is begun in the middle of the spine of the scapula and carried outward to the angle of the acromion. The origin of

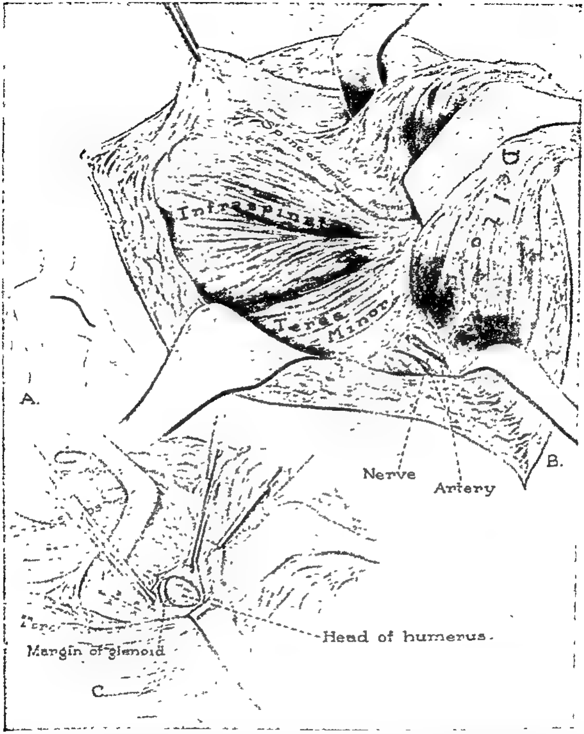


Fig. 13-12. Posterior approach to the shoulder joint similar to that described by Harmon A, the skin incision. B, the origin of the deltoid is separated from the spine of the scapula and posterior margin of the acromion. This muscle is retracted to show the infraspinatus and teres minor muscles. The axillary nerve and artery are protected near the inferior part of the wound. C, the posterior aspect of the joint is exposed by separation of the tendons of the infraspinatus and teres minor muscles and vertical incision in the capsule. (Courtesy Dr. LeRoy C. Abbott and associates.)

the deltoid on the spine of the scapula and the acromion is detached and reflected laterally and inferiorly (Fig. 13-12) In this step the deltoid must not be retracted below the level of the belly of the teres minor muscle lest the axillary nerve be injured. With the arm in a neutral position in regard to rotation, a vertical incision is made through the tendinous portion of the rotator cuff just above the belly of the teres minor and the quadrilateral space. Harmon states that this gives extensive exposure to the humerus, being inferior only to the saber-cut method in the extent of the exposure.

C. Approach of Rowe.

Incision. The incision is begun at the junction of the middle and inner thirds of the spine of the scapula and is extended laterally to the outer segment of the spine It is then curved downward over the posterior aspect of the shoulder joint for about 4 inches. Retraction of the skin exposes the deltoid origin from the spine of the scapula. Approximately 1½ inches from the medial border of the deltoid, this muscle is split in a downward direction for a distance of 3 inches. The portion of the muscle lateral to the vertical incision through its substance is formed into a triangular flap by subperiosteal reflection of its origin from the spine of the scapula. This exposes the infraspinatus and teres minor muscles. The approach to the joint is secured by separating these two muscles and freeing the infraspinatus from the underlying capsule. The tendon of attachment of the infraspinatus is divided ½ inch from its insertion into the greater tuberosity and is retracted medially. Retraction of the teres minor inferiorly exposes the capsule of the posterior and inferior aspects of the shoulder joint. Rowe emphasizes the importance of keeping the incision above the teres minor in order to avoid injury to the axillary nerve which passes here through the quadrilateral space. The interior of the posterior and inferior aspects of the shoulder joint can be adequately exposed by a vertical incision through the capsule.

D. Posterior U-shaped Flap.

1. *Indications.* (a) Arthrodesis of the shoulder, (b) posterior dislocation of the shoulder, (c) injuries to the axillary nerve.

2. *Position of the Patient.* The patient is in the sitting position on the operating table with the shoulder projecting beyond the edge of the table.

3. *Anesthesia.* Intratracheal anesthesia is preferable with the head fixed with a special head rest.

4. *Landmarks.* (a) Spine of the scapula, (b) angle of the acromion.

5. *Incision.* The skin incision starts about 2 inches below the spine of the scapula at the junction of the inner and middle thirds. The line of incision extends upward across the spine and then swings laterally as far as the angle of the acromion. Here it curves downward to overlie the tendinous avascular interval, separating the posterior and middle thirds of the deltoid muscle for a distance of about 3 inches (Fig. 13-13A). The incision is deepened through the subcutaneous tissue and the posterior border of the deltoid is identified, as well as the posterior avascular interval. The deltoid is then freed from the scapular spine subperiosteally, split longitudinally in the avascular interval, and turned down as a skin muscle

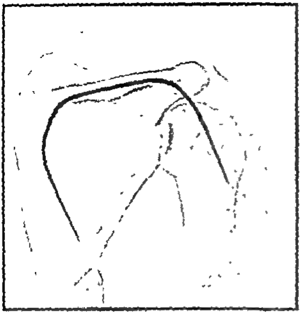
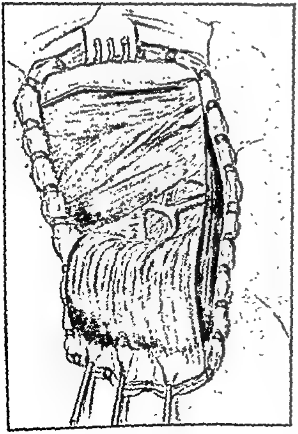


Fig. 13-13. A, inverted U-shaped incision for exposure of the posterior aspect of the shoulder. B, skin muscle flap turned down with exposure of quadrilateral space and rotator cuff. C, exposure of the joint as secured by section of the rotator cuff and capsule. (From Abbott, L. C., and Lucas, D. B. Ann. Surg., 136:392, 1952. Courtesy Dr. LeRoy C. Abbott and associates.)

A



B

C

flap, to expose the underlying infraspinatus and teres minor muscles. When the flap has been turned down a distance of about 2 inches the quadrilateral space comes into view (Fig. 13-13B). The posterior humeral circumflex artery and axillary nerve emerge after they have separated into anterior and posterior divisions. The longitudinal split between the two segments of the deltoid passes between these divisions of the artery and nerve in such a way that they are not injured. Further splitting of the muscle may be carried out as far distally as its insertion on the humerus. This permits adequate exposure for exploration of the quadrilateral space. To expose the glenohumeral joint, the cuff is sectioned in its tendinous portion and the corresponding muscles are allowed to retract. The joint capsule is then divided to permit free access to the posterior aspect of the joint (Fig. 13-13C). Closure is effected by repairing the capsule and cuff. The deltoid muscle is approximated along the avascular interval and is reattached to the aponeurosis of the trapezius along the spine of the scapula. Suture of the subcutaneous tissue and skin completes the closure.

IV. Approaches to the Inferior Aspect of the Joint.

Approaches to the inferior aspect of the shoulder joint may be achieved by the method of Thomas, who reaches the capsule at the inferior aspect of the joint by an incision along the margin of the posterior fold of the axilla. To our knowledge this approach is not in use at the present time. Other approaches to the axilla, usually for purposes of drainage of the axillary space, are made along the inferior margin of the pectoralis major. Incisions of this type may occasionally be needed for drainage of pus which has migrated from the shoulder joint to the axilla, or more commonly for accumulations of pus arising from infected axillary glands.

THE ELBOW JOINT

General Anatomic Considerations. The elbow joint, a combined hinge and pivot joint, has three articulations, one between the trochlea of the humerus and the semilunar notch of the ulna, another between the capitellum and the head of the radius, and the third between the head of the radius and the radial notch of the ulna. A capsule which is reinforced at the sides by ligaments surrounds the joint. Proximally, the capsule attaches to the anterior surface of the humerus above the coronoid and radial fossae, at the sides to the epicondyles, and posteriorly to a line through the upper olecranon fossa Below, it attaches to the olecranon, the coronoid process of the ulna, and the annular ligament. The radial collateral ligament arises from the distal part of the lateral epicondyle and attaches below to the lateral aspect of the olecranon and the annular ligament of the radius, which surrounds the radial head to hold it in the radial notch of the ulna. The ulnar collateral ligament attaches to the medial epicondyle and divides distally into three parts. The anterior segment inserts into the coronoid, the posterior segment attaches to the olecranon, while the transverse segment serves to deepen the socket for the trochlea of the humerus. The synovial membrane lines the capsule and is reflected upon the nonarticular parts of the bones within it. The fat pads fill the coronoid, radial and olecranon fossae and, though intracapsular, they are covered by syno-

vial membrane which excludes them from the joint. Below the lower border of the annular ligament an extension of the synovial membrane forms a small pouch. Fluid forming in the elbow joint is first palpable on either side of the triceps tendon where the posterior capsule is weakest. With increasing effusion, the dimple on the posterior aspect of the radial head becomes obliterated. On the anterior aspect of the joint the deep fascia is very thick, and pus from an infected joint is forced posteriorly, pointing on either side of the triceps tendon. Aspiration is best accomplished by inserting a needle at a right angle immediately proximal to the head of the radius.

The antecubital fossa is a triangle with its apex downward bounded laterally by the brachioradialis muscle and medially by the pronator teres. The fossa is covered by two layers of fascia, superficial and deep, with a space intervening where the medial basilic and medial cephalic veins course alongside the volar branch of the medial cutaneous and the lateral cutaneous nerves of the forearm. The brachialis anticus and supinator muscles form the floor of the fossa (Fig. 13-14 B and C).

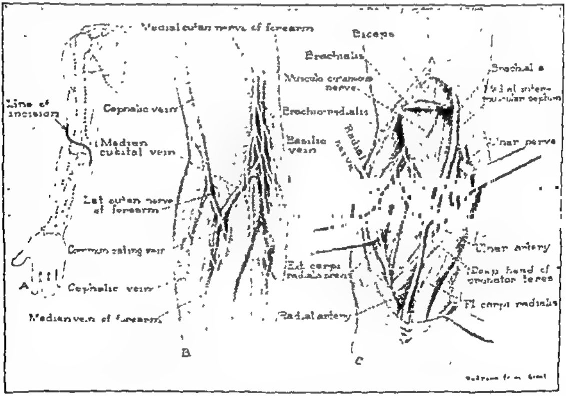


Fig. 13-14. Anatomic dissection of the anterior aspect of the elbow joint. A, skin incision for complete exposure of the anterior aspect of the elbow B, the superficial nerves and veins. C, the musculature in relation to the brachial artery and its divisions, and to the radial, median and ulnar nerves. (After Grant. Courtesy Dr LeRoy C Abbott and associates)

The fossa is divided by the biceps tendon which gives origin on its medial side to the lacertus fibrosus, a strong fascial band which passes medially to blend with the fascia over the origin of the flexor group of muscles. The space contains the brachial artery as it divides into radial and ulnar arteries, their accompanying veins, and the radial and median nerves. On the inner side of the biceps tendon runs the brachial artery, and mesial to it lies the median nerve.

ARTERIES. Two anastomoses encountered in the lateral approaches to the elbow concern the surgeon. In front the terminal anterior branch of the profunda brachii joins the recurrent branch of the radial artery on the anterior surface of the lateral epicondyle. Behind, the radial collateral branch of the profunda brachii meets the recurrent branch of the interosseous, as well as the inferior ulnar collateral, on the posterior surface of the lateral epicondyle beneath the anconeus muscle.

On the inner side of the elbow joint, the anterior branches of the superior and inferior ulnar collaterals join the anterior ulnar recurrent in front of the epicondyle. Behind, the posterior branches of the superior and inferior ulnar collaterals meet the posterior ulnar recurrent in intimate relation with the ulnar nerve. Lying on the brachialis muscle, the brachial artery crosses the joint anteriorly, to divide into the radial and ulnar arteries opposite the neck of the radius. Leaving the fossa, the radial artery follows the medial border of the brachioradialis where the radial recurrent branch arises. No motor nerve crosses this artery. The ulnar artery passes backward beneath the deep head of the pronator teres where it gives rise to the anterior and posterior ulnar recurrent and the common interosseous arteries.

NERVES. The median nerve appears in the antecubital fossa from above, lying on the brachialis muscle medial to the brachial artery. It crosses the fossa, where it produces some motor branches to the flexors, to enter the forearm between the two heads of the pronator teres muscle. The nerve is separated from the ulnar artery at the apex of the fossa by the deep head of the pronator teres.

The radial nerve, on the lateral side, barely enters the fossa. Coursing around the humerus laterally at the juncture of the middle and lower thirds of the bone, it continues anteriorly to lie between the brachioradialis and the brachialis muscles. Here it divides into the superficial radial and posterior interosseous nerves. The posterior interosseous nerve, the important motor branch, proceeds obliquely downward and backward through the substance of the supinator, where it is in close relationship to the head and neck of the radius. Emerging distally, it divides into motor branches to the extensor muscles of the wrist and the fingers.

The ulnar nerve, after passing down the arm behind the intermuscular septum along the medial head of the triceps, enters the ulnar groove behind the medial epicondyle. It crosses the joint posteriorly lying on the ulnar collateral ligament, and dips deep to the two heads of the flexor carpi ulnaris to gain the forearm.

Inserting into the olecranon, the tendon of the triceps covers the joint posteriorly. Laterally, the fascial expansion of the tendon continues downward over the anconeus to blend with the deep fascia of the forearm. The condyles are easily palpable, being subcutaneous. There is a sulcus between the medial epicondyle and the olecranon where the ulnar nerve can be palpated. Just distal to the lateral epicondyle is a dimple where the radial head can be palpated if rotated beneath the finger. Arising from the lateral supracondylar ridge from above downward are the brachioradialis, the carpi radialis, the extensor digitorum communis and the anconeus in the order named. The anconeus is an important landmark as it spreads out to

insert on the lateral surface of the olecranon and the posterior border of the ulna to cover the radiohumeral joint posteriorly. The anconeus muscle is supplied by a branch from the nerve to the medial head of the triceps. In the Kocher incision, this nerve is preserved; but with the incision of Ollier for exposure of the radial head, the muscle is divided and the nerve severed.

The superficial group of flexor and pronator muscles of the forearm have at least part of their origins on the medial epicondyle by virtue of a common tendon. These are the pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimus and the flexor carpi ulnaris arranged in that order from above downward.

SURGICAL APPROACHES TO THE ELBOW JOINT

I Approaches to the Lateral Aspect of the Joint
- A. Straight or Curved Incision (Langenbeck)
- B. Anterolateral Approach

II Approaches to the Medial Aspect of the Joint
- A. Anteromedial Approach
- B Straight or Curved Incision
- C. Straight or Curved Incision with Removal of the Internal Epicondyle (Stiles, Molesworth, Campbell)

III Approaches to the Posterior Aspect of the Joint
- A Straight, Posterior (subperiosteal) Approach for Excision of the Joint
- B Straight Posterolateral Incision (Campbell)
- C. Z-shaped Approach (Ollier)
- D Curved, Posterior Incision (Kocher)
- E Transverse Division of the Triceps (Van Gorder)
- F Oblique Plastic (Campbell)
- G Separation of Tendon from Muscle (Speed)
- H Transverse Incision with Division of the Olecranon
- I Plastic on Olecranon (Albee, Hallock)
- J Darrach Incision

IV. Approaches for Removal of the Head of the Radius
- A. Incision Between the Anconeus and the External Carpi Ulnaris
- B. Incision Between the Common Extensor of the Fingers and the Common Extensor of the Wrist
- C. The Boyd Approach

Vertical incisions about the elbow joint are not desirable since they may lead to keloid formation. Sufficient exposure is often possible through horizontal or semicircular incisions. For more extensive visualization of the joint the incision may be made L-shaped or curved transversely across the joint with longitudinal extremities. On the lateral aspect, gently curved incisions about the condyles are preferable.

I. Approaches to the Lateral Aspect of the Joint.

A. STRAIGHT OR CURVED INCISION (LANGENBECK).

1. *Indications.* (a) Fracture of the lateral condyle, (b) fracture of the head of the radius, (c) epicondylitis.

2. *Position of the Patient.* The arm is supported on a board, the elbow being held at a right angle with the forearm pronated and the lateral epicondyle uppermost.

3. *Landmarks.* (a) Lateral epicondyle, (b) extensor mass, (c) head of the radius.

4. *Incision.* A gently curved incision begins over the lateral supra-

condylar ridge and extends downward to the level of the neck of the radius. The only structure between the fascia and the capsule is the aponeurotic origin of the extensor muscles arising on the lateral condyle and supracondylar ridge. In the distal end of the incision, the supinator brevis is seen. Deep dissection here must be done cautiously lest the posterior interosseous nerve be damaged as it passes laterally to reach the upper border of the supinator at the level of the head of the radius.

B. Anterolateral Approach.

1. *Indications.* Exposure of the capitellum, the head and neck of the radius, the anterior capsule and the radial nerve.

2. *Position of the Patient.* The patient is supine with the shoulder abducted and the elbow extended and supported on an arm board.

3. *Landmarks.* (a) Origin of the extensor muscle group, (b) lateral condyle, (c) head of the radius, (d) biceps tendon.

4. *Incision.* A distinct interval can be felt between the extensor muscle mass laterally and the tendon of the biceps medially. A longitudinal incision with a curved lower transverse segment is made over this interval. In the superficial fascia are found the median cephalic vein running upward and outward toward the cephalic vein, and the lateral cutaneous nerve of the forearm emerging from beneath the musculotendinous juncture of the biceps to cross the interval obliquely. This nerve should not be mistaken for the radial nerve which lies at a deeper level (Fig. 13-14 B and C). After retraction of the biceps medially and the brachioradialis and the origin of the radial extensors laterally, dissection is carried down to reveal the radial nerve lying on the brachialis muscle. The rich anastomosis between the radial recurrent and superior profunda arteries and veins overlies the radial nerve. These vessels may require ligation. The radial nerve must be retracted laterally since the branches to the brachioradialis and extensor carpi radialis longus come from its lateral side The brachialis is retracted medially exposing the anterolateral capsule, the lateral condyle and epicondyle and the annular ligament. By appropriate incisions into the capsule, the capitellum and the head of the radius can be exposed.

II. Approaches to the Medial Aspect of the Joint.

A. Anteromedial Approach.

1. *Indications.* (a) Exposure of the median nerve, (b) transplantation of the origin of the flexor muscles (Steindler), (c) fractures of the internal epicondyle and trochlea, (d) contracture of the anterior capsule of the elbow.

2 *Landmarks.* (a) Biceps tendon, (b) medial epicondyle, (c) flexor muscle mass.

3. *Incision.* The incision is similar to the curvilinear one used for the anterolateral approach The medial basilic vein, encountered in the superficial fascia, is either ligated or retracted medially with the anterior division of the medial cutaneous nerve of the forearm. When the lacertus fibrosus is incised longitudinally, the brachial vessels and median nerve may be seen lying between the biceps tendon and the pronator teres muscle. At the level of the joint the median nerve gives off a branch from its radial side to the superficial head of the pronator teres; all other branches come off on the ulnar side at a lower level. This should be remembered when

the nerve is retracted. Retraction of the median nerve and brachial artery laterally gives an adequate view of the internal epicondyle and a limited exposure of the capsule. An alternate approach may be made between the nerve and the vessel. In deep dissection distally, the radial and ulnar vessels should be protected.

Complete exposure of the front of the elbow is possible through an S-shaped incision over the antecubital space uniting the lower part of the anteromedial and upper half of the anterolateral approaches with a transverse incision across the middle of the anterior surface of the joint (Fig. 13-14 A).

B. Straight or Curved Incision. Space does not permit its description.

C. Straight or Curved Incision with Removal of the Internal Epicondyle (Stiles, Molesworth, Campbell).

1. *Indication.* Fractures of the internal epicondyle and the trochlea.

2. *Position of the Patient.* The arm is abducted and externally rotated with the elbow joint flexed.

3. *Landmarks.* The landmarks are the same as those for the anteromedial approach.

4. *Incision.* Incisions may be vertical, horizontal or curved. The authors prefer the curved incision which begins 2 inches above the epicondyle and extends downward about 4 inches over the flexor muscle mass. The internal epicondyle and intermuscular septum are identified with the common origin of the flexor muscles. The ulnar nerve is found in the substance of the triceps muscle behind the intermuscular septum. Necessary exposure is obtained by subperiosteal reflection. In fractures of this region, particularly of the internal epicondyle, it is of definite importance to make certain that the nerve has not been displaced into the joint or caught in the fracture line.

For more extensive exposure, Molesworth has described an approach from the internal aspect of the elbow with osteotomy of the base of the internal epicondyle. An 8-inch longitudinal incision is made centering over the epicondyle. The ulnar nerve is identified and traced to the interval between the two heads of the flexor carpi ulnaris where the branches to the flexor carpi ulnaris and flexor profundus are freed so that the nerve can be displaced forward. The internal epicondyle is osteotomized and freed from the intermuscular septum. The origin of the pronator teres and flexor muscles is turned forward and downward, care being taken not to injure the median nerve and its branches to the pronator teres. The joint capsule is incised and reflected with its attached structures until the olecranon and the coronoid fossa are exposed. By exaggerating the pronation of the forearm, the entire lower end of the humerus may be brought into view. With retraction of the olecranon, the head of the radius and the semilunar synovial fold can be seen. The epicondyle is replaced and fixed by either sutures or a nail. Campbell has described a similar approach.

III. Approaches to the Posterior Aspect of the Joint.

A, B and C. Space does not permit discussion

D. Curved, Posterior Incision (Kocher).

1. *Indication.* Complete exposure of the joint for arthroplasty, arthrodesis, excision, and for extensive fractures.

2. *Position of the Patient.* The patient is sitting with the arm supported on a Mayo table with the shoulder midway between external and internal rotation, the elbow flexed to 90 degrees, and the forearm in the midposition.

3. *Landmarks.* With flexion of the elbow, the extensor muscle mass and the bony landmarks are identified in order as: (a) lateral supracondylar ridge, (b) lateral epicondyle, (c) head of the radius, (d) olecranon. (Note: the tip of the olecranon is in a line with the epicondyles.)

4. *Incision.* The incision begins on the supracondylar ridge about 2 inches above the joint and passes down over the head of the radius. It then turns medially along the lower border of the anconeus to meet the posterior border of the ulna about 3 inches below the tip of the olecranon. It ends with a gentle curve inward over the medial surface of the ulna.

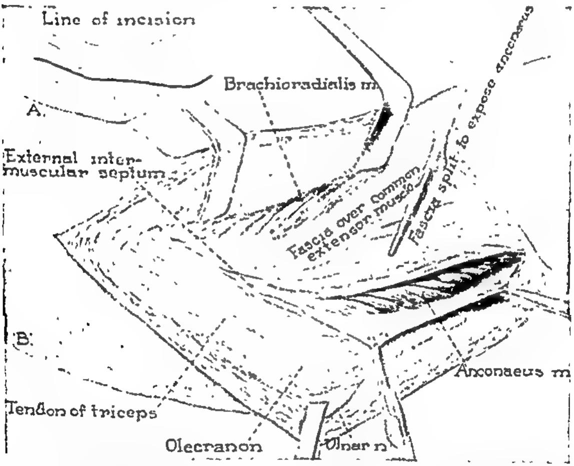


Fig 13-15 Posterolateral approach to the elbow joint (Kocher). A, line of skin incision. B, structures exposed by reflection of the skin (Courtesy Dr. LeRoy C. Abbott and associates.)

The incision is deepened to the epicondylar ridge between the lateral border of the triceps and the origin of the extensors. More distally, it passes between the adjacent borders of the extensor carpi ulnaris and the anconeus to expose the joint capsule, annular ligament and head of the radius. The skin is reflected medially over the olecranon process in order to identify the ulnar nerve (Fig 13-15). The nerve is freed from the groove and retracted medially with a tape. Subperiosteal reflection of the triceps tendon is then begun low on the ulna and continued up over the olecranon

and lower part of the humerus. The lateral condyle of the humerus is then exposed by subperiosteal reflection of the origin of the extensor muscle mass. With retraction of the adjacent borders of the anconeus and the extensor carpi ulnaris muscles, the annular ligament and the supinator brevis muscle are seen to lie respectively in the upper and lower parts of the floor of the wound (Fig. 13-16). The supinator brevis muscle is divided close to its origin from the ulna and the posterior part of the annular liga-

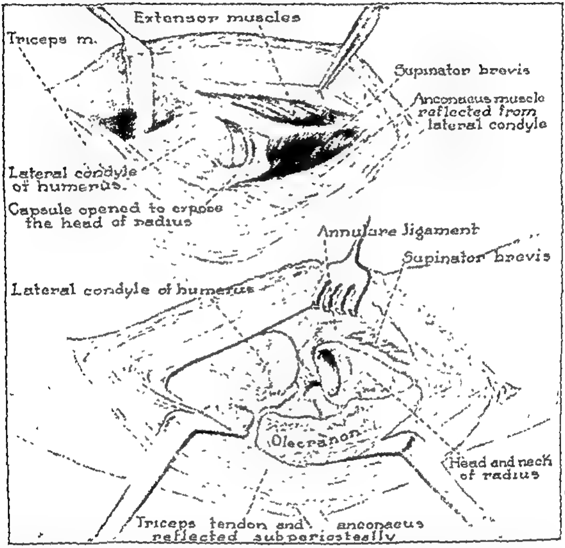


Fig 13-16. A, reflection of the origin of the common extensor and anconeus muscles with division of the capsule of the radiohumeral joint. B, complete exposure of the elbow joint (Courtesy Dr LeRoy C Abbott and associates)

ment is incised obliquely to reveal the head of the radius. It is during the performance of this part of the operation that there is danger of injury to the posterior interosseous nerve as it passes obliquely through the substance of the supinator brevis around the neck of the radius to gain the posterior aspect of the forearm. If the operation calls for complete exposure of the neck of the radius and upper shaft of this bone, the authors have used a method similar to that of Boyd and have reflected the supinator muscle laterally with the nerve or, on occasions, have identified the nerve at its entrance to and exit from the supinator muscle.

Closure is done in two layers. The periosteum is first repaired. The deep fascia over the biceps and extensors is united as are the adjacent margins of the extensor carpi ulnaris and anconeus. The triceps tendon falls back in place.

E. Transverse Division of the Triceps. Van Gorder exposes unreduced elbow dislocations through a vertical incision with transverse division of the triceps tendon. He removes all scar and callus and gently manipulates the parts back into place. The triceps is repaired by a transplant of either fascia or tendon.

F. Oblique Plastic. Space does not permit its discussion.

G. Separation of Tendon from Muscle. To reduce an old dislocation of the elbow, Speed uses a curved posterior incision separating the triceps tendon from the muscle obliquely. He splits the lower part of the triceps vertically and reflects subperiosteally the muscle attachment to the humerus. It is important to excise all scar and remove any callus from the olecranon fossa. Reduction of the head of the radius should precede reduction of the olecranon.

H. Transverse Incision with Division of the Olecranon.

1. *Indications.* (a) Arthrotomy, (b) removal of loose bodies, (c) arthroplasty.

2. *Position of the Patient.* The patient is supine with the elbow flexed over the chest.

3. *Landmarks.* (a) Tip of the olecranon, (b) lateral epicondyle, (c) medial epicondyle.

4. *Incision.* A semicircular incision is made beginning at the medial epicondyle, passing downward in a gentle curve to cross the ulna about 2 inches distal to the tip of the olecranon and then continuing upward to terminate over the lateral epicondyle. The flap of skin and subcutaneous tissue is dissected upward to the level of the epicondyles (Fig. 13-17). The ulna nerve is identified as it passes between the two heads of the flexor carpi ulnaris. It is then freed from the epicondylar groove and retracted medially; care being taken to preserve the motor branches to the flexor carpi ulnaris (Fig. 13-18 A). The ulnar head of the flexor carpi ulnaris and the anconeus are dissected free for a short distance along the ulna and the triceps tendon is isolated. The olecranon is osteotomized in a V-shaped manner 1 inch from its tip and retracted proximally together with the triceps tendon (Fig. 13-18 B).

Closure is effected by replacement of the olecranon which is secured with an axial screw (Fig. 13-18 C) The muscles are reattached to the olecranon and the skin flap is sutured in place

I. Plastic on Olecranon. Space does not permit its discussion.

J. Darrach Incision. Space does not permit its discussion.

IV. Approaches for Removal of the Head of the Radius.

1 *Indications.* (a) Fractures of the head and neck of the radius, (b) dislocation of the head of the radius, (c) drainage of the elbow joint.

2. *Position of the Patient* The patient is in the sitting position used for the Kocher approach.

3. *Landmarks.* The landmarks are the same as those for the Kocher approach.

4. *Incision.* With the object of exposing the radial head without damage to the posterior interosseous nerve a variety of incisions have been made which vary from straight lateral to oblique and posterolateral incisions.

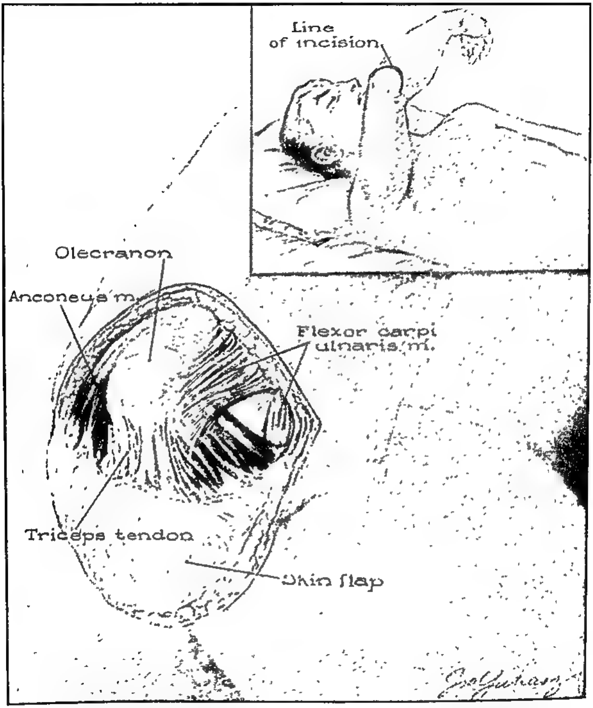


Fig. 13-17. Transverse approach with division of the olecranon Skin flap dissected proximally. (Courtesy Dr. LeRoy C. Abbott and associates)

A. Incision Between the Anconeus and the External Carpi Ulnaris. The incision extends downward from the lateral epicondyle to a point on the ulna 3 inches distal to the tip of the olecranon. The anconeus and the extensor carpi ulnaris are separated to expose from above downward the capsule, the annular ligament and the supinator brevis muscle. The head and neck of the radius are exposed by dividing the capsule obliquely.

B. Incision Between the Common Extensor of the Fingers and the Common Extensor of the Wrist. As there is less danger of injury to the posterior interosseous nerve by this approach, the writers prefer it to other incisions which either separate the extensor carpi ulnaris from the common extensor of the fingers or separate the common extensor of the fingers from the radial extensors.

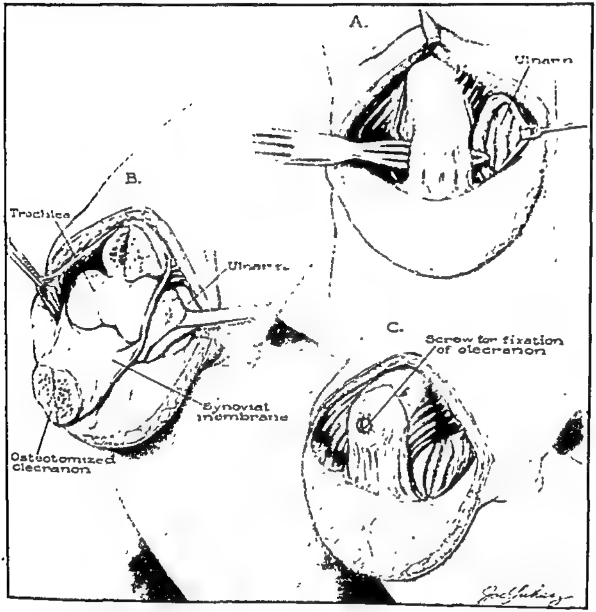


Fig. 13-18. A, ulnar nerve exposed and flexor carpi ulnaris and anconeus partially detached B. olecranon osteotomized in V-shaped manner C, reattachment of olecranon with axial screw prior to closing skin flap (Courtesy Dr LeRoy C Abbott and associates)

C. The Boyd Approach. Boyd has described a similar but more extensive posterior approach which exposes the ulna and proximal third of the humerus by one incision.

"The incision is begun at a point ¾ inch proximal to the tip of the olecranon on the external border of the triceps tendon and is extended downward along this structure to its insertion into the olecranon, thence is continued along the radial side of the subcutaneous triangle, which forms

the dorsal surface of the olecranon, to the apex of the triangle. From this point the incision follows the dorsal border of the ulna distally, if necessary, to the styloid process. On the radial side of the incision are the anconeus and extensor carpi ulnaris muscles, while on the ulnar side are the distal portion of the triceps tendon and the flexor carpi ulnaris and flexor digitorum profundus muscles (Fig. 13-19).

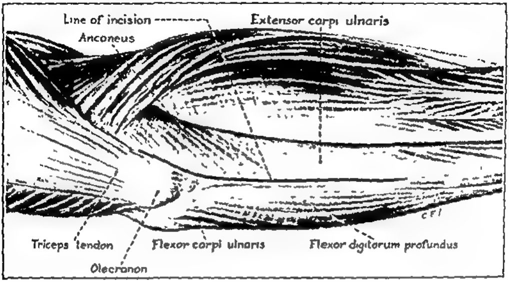


Fig. 13-19 Line of incision (From Boyd, H. B. Surg., Gynec. & Obst, 71:86, 1940.)

"The insertion of the anconeus and origin of the supinator muscles are elevated subperiosteally from the dorsal surface of the ulna, as are also the origins of the abductor pollicis longus, extensor carpi ulnaris, and extensor pollicis longus muscles throughout the extent of the incision. Stripping of these structures, being subperiosteal, is accomplished with ease. The deep muscle fibers of the supinator which arise from the triangular depression below the radial notch are next divided close to the ulna.

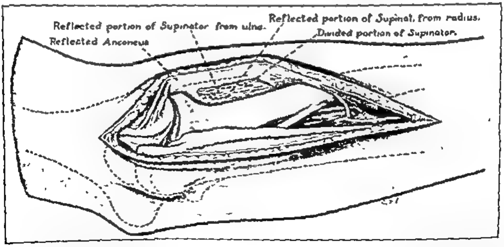


Fig. 13-20 Complete exposure of the upper third of the ulna, upper fourth of the radius, and radiohumeral articulation (From Boyd, H B Surg, Gynec & Obst, 71:86, 1940)

"The muscular flap may now be retracted radially to expose the radiohumeral articulation, the head and neck of the radius, and that portion of the shaft above the upper margin of the interosseous membrane (Fig.

13-20). If further exposure of the radius is desired, the dorsal interosseous artery may be ligated at the upper margin of the membrane and the muscular flap reflected subperiosteally from the ulna down to the interosseous membrane, thence laterally along the dorsal surface of the membrane to the radius. In this manner, slightly more than the upper third of the radius may be exposed without disturbing the deep branch of the radial nerve."

THE WRIST JOINT AND THE JOINTS OF THE HAND

General Anatomic Considerations. The wrist is a complex of several joints, namely the inferior radio-ulnar, the radiocarpal, the transverse intercarpal, the carpometacarpal and the intermetacarpal joints (Saunders).

The inferior radio-ulnar joint is formed by the distal ends of the radius and ulna and the triangular fibrocartilage. The base of the latter is attached to the ulnar margin of the radius while its apex is fixed to the root of the styloid process of the ulna. The capsule of the joint is a loose structure which is attached to the anterior and posterior surfaces of the lower ends of the radius and ulna and to the adjacent surfaces of the triangular fibrocartilage. The synovial membrane lines the joint capsule and extends between the inferior aspect of the head of the ulna and the articular disc, and upward between the adjacent surfaces of the lower ends of the radius and ulna.

The radiocarpal joint, the wrist joint proper, is formed by the articulation of the lower end of the radius and the triangular fibrocartilage with the proximal row of carpal bones. The fibrous capsule of this joint is reinforced by the anterior and posterior radiocarpal ligaments and by the radial and ulnar collateral ligaments.

The transverse intercarpal joint is a compound joint between the proximal and distal rows of carpal bones. The main part of the cavity of the joint lies between the bones of the proximal and distal rows, with two prolongations of the joint passing proximally, and three passing distally between the individual bones composing these rows.

A common joint exists between the distal row of the carpus and the bases of the metacarpal bones, except in the case of the first metacarpal bone where a separate articulation is formed with the greater multiangular bone. A separate joint is also formed between the pisiform and the triquetrum. The various ligaments of the intercarpal, carpometacarpal and proximal intermetacarpal joints constitute collectively a single capsule which surrounds a single joint cavity. The synovial membrane lines this capsule and extends over all the parts of the bone within the capsule which are not covered by articular cartilage.

Flexion and extension at the wrist occur mainly at the radiocarpal and transverse intercarpal joints. From the midposition, the greater part of flexion occurs at the transverse intercarpal joint, while extension occurs for the most part at the radiocarpal joint.

Aspiration of the radiocarpal joint is carried out immediately distal to the styloid process of the ulna between the tendons of the flexor and extensor carpi ulnaris muscles.

Surgical Landmarks. The proximal and distal transverse creases in the skin on the anterior surface of the wrist help the surgeon in locating the deeper structures. Beneath the distal transverse crease at its radial end, the tubercle of the scaphoid can be palpated while at the ulnar end of the crease, the pisiform can be felt. Both creases are crossed on the radial side of the wrist by the tendon of the flexor carpi radialis muscle, in the center by the tendon of the palmaris longus muscle, and on the ulnar side by the tendon of the flexor carpi ulnaris.

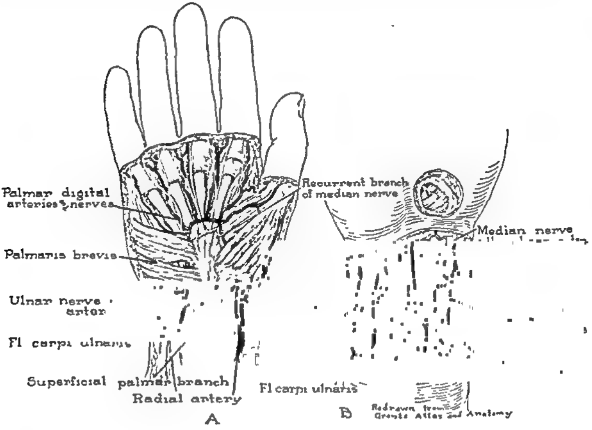


Fig 13-21 Anatomic dissections of the wrist and hand. (After Grant. Courtesy Dr. LeRoy C. Abbott and associates.)

The radial artery can be palpated on the anterior surface of the lower end of the radius lateral to the tendon of the flexor carpi radialis. From here it leaves the forearm to wind around the radial side of the wrist lying on the radial collateral ligament. It then proceeds distally to cross the dorsal surfaces of the navicular and the greater multiangular bones. Here it lies on the floor of the anatomic snuff box, the borders of which are formed by the abductor pollicis brevis and the extensor pollicis brevis on the radial aspect and by the extensor pollicis longus muscle on the ulnar aspect. The radial artery finally disappears from view by turning volarward through the proximal part of the first interosseous space, between the heads of origin of the first dorsal interosseous muscle. Then it runs between the oblique and transverse heads of the adductor pollicis brevis muscle where it joins the ulnar artery to form the major portion of the deep palmar arch (Fig. 13-21).

The ulnar artery and ulnar nerve follow the medial border of the tendon of the flexor carpi ulnaris muscle and the medial surface of the

pisiform bone superficial to the transverse carpal ligament. At the distal border of this ligament the ulnar artery gives off the profunda branch which joins the radial artery to form the deep palmar arch. The ulnar nerve also divides at this level into its superficial and deep branches.

The transverse carpal ligament is a dense fibrous structure which is attached on the radial side to the tubercle of the scaphoid and the ridge of the greater multiangular bones. On its ulnar side it is attached to the pisiform and the hook of the hamate. The proximal margin is continuous with the deep fascia of the forearm while on its distal margin it is prolonged to form the intermediate part of the palmar aponeurosis. The transverse carpal ligament together with the carpus forms an osteofibrous tunnel for the passage of the flexor tendons of the fingers and thumb and of the median nerve from the forearm to the palm of the hand. On the radiopalmar aspect of the ligament, the volar branch of the radial artery crosses the palm where it is joined by the superficial branch of the ulnar artery to form the superficial volar arch. Two synovial sheaths pass beneath the ligament, one for the flexor pollicis longus and the other for the flexor digitorum sublimus and flexor digitorum profundus. The median nerve lies on the radial side of the sheath for the flexor digitorum sublimus.

On the dorsal aspect of the wrist the bony landmarks are the radial and ulnar styloids, the head of the ulnar and the dorsal tubercle of Lister. The radial styloid lies a little more anterior than the ulnar styloid and into it is inserted the tendon of the brachioradialis muscle. The tubercle of Lister is a prominence on the dorsal aspect of the lower end of the radius which separates the extensor tendons of the fingers from the radial extensors of the wrist. The dorsal carpal ligament is a thickened portion of the deep fascia of the forearm lying more proximal than the transverse carpal ligament. It is attached to the radial and ulnar styloids and from its deep surface partitions pass to ridges on the dorsal surfaces of the radius and ulna to form osteofascial tunnels for the passage of the extensor tendons of the fingers and thumb from the forearm to the hand (Fig. 13-22B).

The exact location of the cutaneous nerves at the level of the wrist is of importance to the surgeon. A hand's breadth proximal to the radial styloid the superficial branch of the radial nerve passes from the anterior surface of the arm to the dorsum of the wrist under the tendon of the brachial radialis muscle. Here it divides into its several branches which supply the radial side of the back of the wrist and the contiguous surfaces of the thumb, index and middle fingers. The dorsal branch of the ulnar nerve winds around the back of the wrist immediately below the prominence formed by the distal end of the ulna. It then divides into its three cutaneous branches which supply the ulnar margin of the little finger, the contiguous surfaces of the little and ring fingers and, together with the radial nerve, the contiguous surfaces of the ring and middle fingers (Fig 13-22A).

The carpometacarpal joint is the joint between the bases of the second to the fifth metacarpal bones and the distal articular facets of the lesser multiangular, a small portion of the greater multiangular, the capitate and the hamate bones. The articular cavity is usually single though it often

communicates with the intercarpal joint between the capitate and the lesser *multiangular bones. Motion in the carpometacarpal articulation is* greatly restricted, particularly between the bases of the second and third metacarpals and the corresponding bones of the carpus. Movement takes place on hollowing and flattening the palm and during opposition of the little finger.

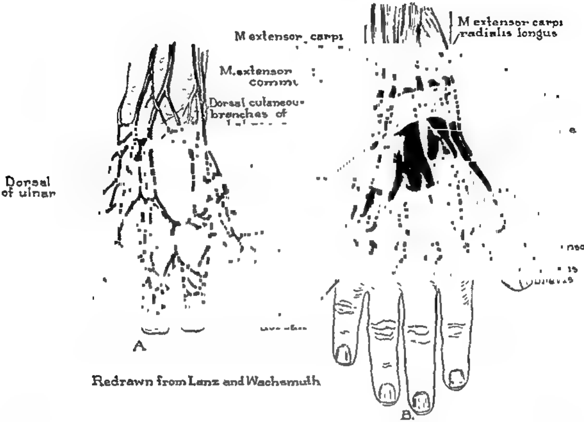


Fig 13-22 Anatomy of dorsum of wrist and hand A, cutaneous nerves and veins B, the tendons and their synovial sheaths. (After Lanz and Wachsmuth. Courtesy Dr. LeRoy C Abbott and associates.)

The carpometacarpal joint of the thumb is formed by the saddle-shaped articular facet of the greater multiangular bone and the base of the first metacarpal bone. It is always an independent articulation surrounded by a capsular ligament sufficiently lax to permit a considerable range of motion in abduction, extension and opposition.

The metacarpophalangeal joints are formed by the heads of the metacarpals and the bases of the proximal phalanges. The articular capsules are thin and somewhat relaxed but they are reinforced by strong lateral ligaments which are eccentrically inserted into the heads of the metacarpals so that they become tense during flexion of the phalanges. The anterior surfaces of the capsules are reinforced by accessory volar ligaments, which are connected with the sheaths of the flexor tendons and by the transverse capsular ligaments, the strong flat bands which connect the heads of the second to the fifth metacarpal bones. The metacarpophalangeal joint of the thumb always contains two sesamoid bones, a radial and an ulnar, which are embedded in the capsule, and are covered by cartilage on their articular surfaces. The motions permitted at the meta-

carpophalangeal joints are flexion and extension. In flexion the lateral ligaments are tense and prevent any lateral movement whereas in extension these ligaments are relaxed and allow for abduction and adduction.

The middle and distal interphalangeal joints have ligaments arranged upon the same plan as that of the metacarpophalangeal joints. The articulations are purely hinge joints.

SURGICAL APPROACHES TO THE WRIST JOINT AND THE JOINTS OF THE HAND

I. Approaches to the Anterior Aspect of the Wrist
 A. Approach of Lipshutz
 B. Approach of Campbell

II. Approaches to the Dorsal Aspect of the Wrist
 A. Curvilinear Incision for Arthrodesis
 B. Double Incisions (Lister and Ollier)
 C. Dorso-ulnar Incision (Kocher)
 D. Dorsoradial Incision (Langenbeck)

III. Approach to the Radial Aspect of the Wrist Joint

IV. Approaches to the Ulnar Aspect of the Wrist
 A. Approach of Darrach
 B. Approach of Smith-Petersen

V. Approach to the Carpometacarpal Joint of the Thumb

VI. Approaches to the Metacarpophalangeal and Interphalangeal Joints

I. Approaches to the Anterior Aspect of the Wrist.

A. Approach of Lipshutz.

1. *Indications.* (a) Fractures of the lower end of the radius, (b) fractures of the lower end of the ulna, (c) fractures and dislocations of the carpus with anterior displacement of fragments.

2. *Position of the Patient.* The arm is supported on an arm board at right angles to the trunk with the elbow in extension and the forearm in supination.

3. *Landmarks.* (a) Radial and ulnar styloids, (b) creases on the volar surface of the wrist joint, (c) pisiform and scaphoid bones, (d) tendons of the flexor carpi ulnaris and palmaris longus.

4. *Incision.* The incision may be longitudinal or transverse, the latter being preferable as healing takes place with less scarring. A vertical incision may be necessary to provide adequate exposure in certain fractures of the lower end of the radius or ulna. Lipshutz has described such an approach for reduction of fractures of the lower end of the radius with ventral displacement of the lower fragment. The incision begins just medial and distal to the pisiform bone and is continued upward along the course of the tendon of the flexor carpi ulnaris for a distance of about [illegible] cm. The deep fascia is incised and the tendons of the flexor sublimus and profundus muscles are retracted to the radial side and the tendon of the flexor carpi ulnaris to the ulnar side. In the interval thus provided the ulnar artery and ulnar nerve are identified and followed to the radial side of the pisiform. Here they lie superficial to the transverse carpal ligament and are covered by the palmaris brevis muscle (Fig. 13-21A). They are retracted to

communicates with the intercarpal joint between the capitate and the lesser multiangular bones. Motion in the carpometacarpal articulation is greatly restricted, particularly between the bases of the second and third metacarpals and the corresponding bones of the carpus. Movement takes place on hollowing and flattening the palm and during opposition of the little finger.

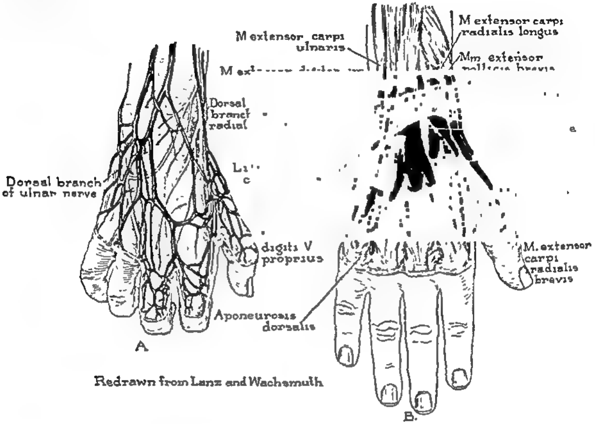


Fig 13-22. Anatomy of dorsum of wrist and hand. A, cutaneous nerves and veins. B, the tendons and their synovial sheaths. (After Lanz and Wachsmuth. Courtesy Dr. LeRoy C. Abbott and associates)

The carpometacarpal joint of the thumb is formed by the saddle-shaped articular facet of the greater multiangular bone and the base of the first metacarpal bone. It is always an independent articulation surrounded by a capsular ligament sufficiently lax to permit a considerable range of motion in abduction, extension and opposition.

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bone grafts which are to be placed later are fitted into a notch in the lower end of the epiphysis of the radius. With a curet and a sharp knife, the cartilage is then removed from the lunate, navicular, os capitate and the greater and lesser multiangular bones. The spaces between the denuded surfaces of the carpal bones and the lower end of the radius are packed with chips of cancellous bone taken from the ilium, and broad, pliable sections from the same source are then placed over the entire posterior aspect of the radiocarpal and transverse intercarpal joints (Fig. 13-24). Fixation of these grafts is secured by tucking their upper and lower borders beneath the bases of the bone flaps which were raised from the

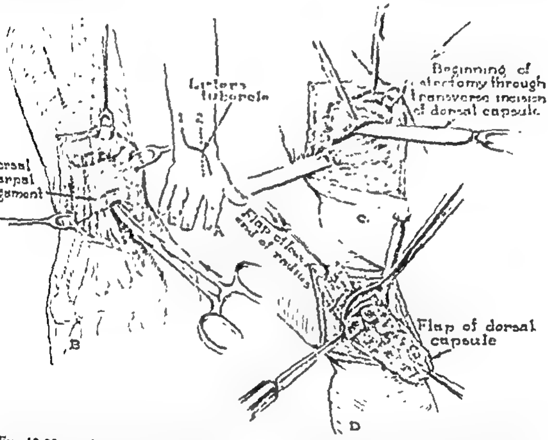

Fig. 13-23. A, skin incision. B, dorsal carpal ligament and extensor tendons. C, the radiocarpal joint is opened through a transverse incision. The beginning of the osteotomy of the lower end of the radius and the dorsal flap is shown. D, the flaps are raised and the radiocarpal and intercarpal joints are exposed. The cartilage is removed from the radiocarpal joint with a curved gouge. (After Abbott, Saunders, and Bost. Courtesy Dr LeRoy C Abbott and associates.)

posterior aspect of the carpus and radius and by dorsiflexion of the wrist. The inferior radio-ulnar and the carpometacarpal joints are not exposed. The preservation of movement at the inferior radio-ulnar joint allows for normal rotation of the forearm, and for the piston-like action of the radius on the ulna, which is essential for good function of the wrist and hand. As the carpometacarpal joints are left intact, the metacarpal arch of the hand is maintained, and the power and strength of the grasp is preserved. Moreover, the few degrees of motion remaining in these joints allow sufficient movement to absorb the shocks encountered in the course of everyday activity.

the ulnar side with the tendon of the flexor carpi ulnaris muscle. In the floor of the wound, the radiocarpal ligament is incised and the anterior margin of the lower end of the radius, the radiocarpal joint, and the triangular fibrocartilage are exposed.

B. Approach of Campbell. Campbell has described an anterior incision which follows the distal crease at the wrist. After division of the skin and the superficial and deep fasciae, the tendon of the palmaris longus muscle is identified. The median nerve lies at a deeper level between this tendon and the tendon of the flexor carpi radialis muscle (Fig. 13-21B). At a still deeper level, the tendon of the flexor pollicis longus is retracted to the radial side and the tendons of the flexor sublimus and flexor profundus are retracted to the ulnar side. Between these tendons the anterior capsule is incised and the lower anterior margin of the radius and the proximal surfaces of the scaphoid and lunate bones are exposed.

II. Approaches to the Dorsal Aspect of the Wrist.

A. Curvilinear Incision for Arthrodesis.

1. *Indications.* This incision is generally employed in fusion of the wrist joint. It may also be used for partial excision of the wrist or for fractures involving the lower end of the radius, the lunate or the navicular bones.

2. *Position of the Patient.* The arm is supported on an arm board at right angles to the trunk, with the elbow in extension and the forearm in pronation.

3. *Landmarks.* (a) Radial and ulnar styloids, (b) tubercle of Lister, (c) extensor tendons of the fingers, (d) extensor tendons on the radial aspect of the wrist.

4. *Incision.* A pneumatic cuff is used as a tourniquet. An incision which may be straight or, preferably, curvilinear is made over the posterior aspect of the wrist with its center over the dorsal tubercle of Lister (Fig. 13-23A). On retraction of the skin and subcutaneous tissue, the dorsal carpal ligament is exposed, and the several fibrous partitions which separate the tendon sheaths over the lower parts of the radius and ulnar are clearly seen (Fig. 13-23B). This ligament, together with the periosteum, is incised vertically over Lister's tubercle. The posterior aspect of the lower end of the radius is then exposed subperiosteally, care being taken to preserve as far as possible the sheaths of the tendons of the extensor pollicis longus, the extensors carpi radialis longus and brevis, and the extensor digitorum communis. These tendon sheaths are retracted to the radial and ulnar sides in order to expose the dorsal aspect of the radiocarpal and intercarpal joints. The posterior ligament of the radiocarpal joint is incised horizontally along the lower margin of the radius. The wrist is then held in palmar flexion while, with a special gouge, the cartilage is removed from the lower end of the radius and the superior surfaces of the navicular and lunate (semilunar) bones (Fig. 13-23D). The intercarpal and the transverse intercarpal joints are exposed en masse by turning distally, with the aid of an osteotome, a curved flap, consisting of the fibrous capsule of these joints together with a thin section of cortex from the posterior surfaces of the navicular, lunate and capitate bones. In adults, a thin flap of bone from the dorsal aspect of the radius is then cut and turned upward with an osteotome (Fig. 13-23C). To avoid injury to the epiphysial line in children, this latter step is omitted and the

the axis of the forearm for a distance of 1½ inches. The second incision is made on the ulnar aspect of the extensor carpi ulnaris tendon and extends from a point 1½ inches above the tip of the ulnar styloid to a point ¾ of an inch below the base of the fifth metacarpal bone. This incision penetrates directly to the bone. Through the two incisions a thorough subperiosteal reflection of the dorsal surface of the carpus is accomplished. Care is taken to preserve the insertions of the various tendons into the bones. Excision of the carpus is then carried out, usually beginning with the removal of the semilunar preserving if possible the pisiform, the trapezium and the hook of the hamate.

C. Dorso-ulnar Approach of Kocher. Kocher described two approaches for excision of the wrist. He objected to the dorsoradial approach because the detachment of the insertions of the radial extensors caused weakness in dorsiflexion of the wrist. The dorso-ulnar incision extends from the middle of the fifth metacarpal bone upward over the middle of the wrist joint and lower part of the forearm. At the lower end of the incision, the origin of the posterior ulnar vein and the dorsal branch of the ulnar nerve are to be avoided. After dividing the fascia, along with the strong transversely striated posterior annular ligament, the incision exposes the sheaths of the extensor minimi digiti and the extensor communis tendons which are drawn to the radial side. Beneath the tendons, the ligaments which are attached to the base of the fifth metacarpal, the triquetrum, the hamate and the ulnar are divided. The capsule is now separated to the ulnar side and along with it the tendon of the extensor carpi ulnaris is reflected subperiosteally, its attachment to the fifth metacarpal being preserved. Kocher states that the detachment of the insertion of the extensor carpi ulnaris produces less interference with the motion of dorsiflexion of the wrist than when the insertion of the radial extensors is detached. The tendon of the extensor carpi ulnaris is lifted from its groove in the ulna and here the capsule is separated from around the bone. When the inferior radio-ulnar joint is diseased the triangular fibrocartilage is removed. After division of the capsule of the triquetrum, the joint between it and the pisiform is opened; this bone is left intact with its insertion of the flexor carpi ulnaris. The hook of the hamate is sectioned at its base, the deep branch of the ulnar nerve being preserved. The bundle of flexor tendons can now be lifted from its groove and the ligamentous connections between the three inner metacarpals can be separated upon the palmar aspect. The insertion of the flexor carpi radialis is retained and the attachment of the anterior ligament of the wrist joint is separated from the anterior border of the lower end of the radius On the dorsal aspect the posterior ligament is detached from the lower end of the radius as far as the radial extensors of the wrist and the extensors of the thumb. These tendons are in turn raised from their grooves and their insertions preserved. The hand is now completely dislocated toward the radial side of the wrist so that the thumb comes to lie in contact with the radial border of the forearm. With this wide exposure, there is no difficulty in removing the individual carpal bones and the adjacent margins of the radius, ulna and metacarpal bones.

D. Dorsoradial Incision of Langenbeck. Space does not permit discussion.

The wound is closed by silk sutures which approximate the margins of the bone flaps, the periosteum on the lower end of the radius, and the ligaments. A plaster-of-paris cast is then applied, which extends from the upper arm to the tips of the fingers and the thumb, with the elbow held at a right angle, the forearm in the midprone position and the wrist in from 10 to 15 degrees of extension with the joints of the thumb and fingers in moderate flexion. The cast is carefully molded about the wrist and the palmar surfaces of the hand and fingers, and is cut over the back of the wrist and forearm to allow for swelling.

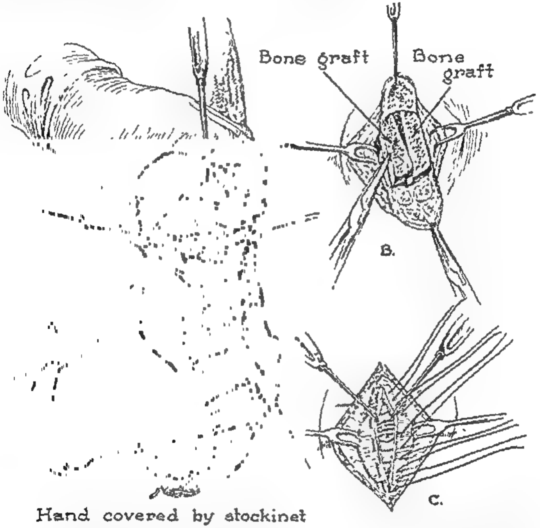

Fig. 13-24. A, curved grafts are placed in the radiocarpal joint, and chip grafts are fitted into the intercarpal and transverse intercarpal joints B, long grafts cover the lower end of the radius and the denuded carpal bones The ends of the grafts are tucked beneath the bases of the radial and carpal bone flaps C, the margins of the flaps are approximated with mattress sutures lying deep in the transverse plane Vertical mattress sutures close the dorsal carpal ligament. (Courtesy Dr LeRoy C Abbott and associates)

B. Double Incisions of Ollier and Lister. The incisions of Ollier and Lister have been employed largely for radical excision of the wrist joint in tuberculosis.

Ollier used two incisions, one beginning on the dorsal aspect of the middle of the second metacarpal bone and extending along the radial aspect of the tendon of the extensor indices proprius to the level of the interstyloid line where it changes its direction and continues parallel to

the axis of the forearm for a distance of $1\frac{1}{2}$ inches. The second incision is made on the ulnar aspect of the extensor carpi ulnaris tendon and extends from a point $1\frac{1}{2}$ inches above the tip of the ulnar styloid to a point $\frac{3}{4}$ of an inch below the base of the fifth metacarpal bone. This incision penetrates directly to the bone. Through the two incisions a thorough subperiosteal reflection of the dorsal surface of the carpus is accomplished. Care is taken to preserve the insertions of the various tendons into the bones. Excision of the carpus is then carried out, usually beginning with the removal of the semilunar preserving if possible the pisiform, the trapezium and the hook of the hamate.

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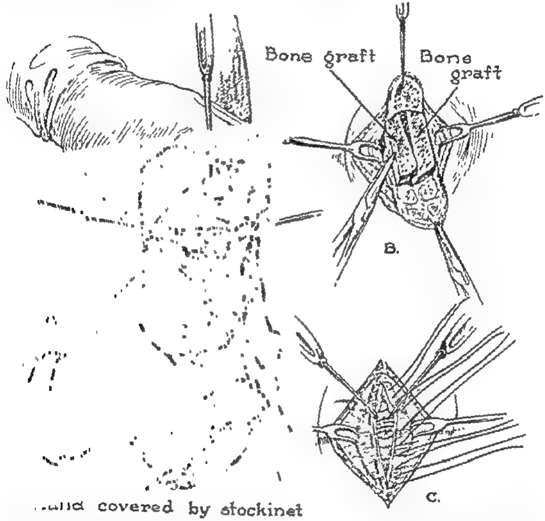

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to the styloid; it then curves anteriorly in the direction of the proximal end of the fifth metacarpal to run parallel with this bone for a distance of approximately 1 inch. A bayonet incision of this type results in two flaps which are easily retracted.

After division of the subcutaneous fat and fascia, the ulnar periosteum is incised and the lower end of the ulna is exposed subperiosteally. Following an oblique osteotomy, the distal inch or so of the ulna is removed and the capsule and ligaments are reflected subperiosteally from the radius and carpus exposing the radiocarpal joint. The increased mobility thus obtained facilitates the complete removal of the cartilage from the radius and placing of the bone graft.

V. Approach to the Carpometacarpal Joint of the Thumb. For correct incisions on the hand the reader is referred to Bunnell's excellent book, *Surgery of the Hand.*

Operation upon the carpometacarpal joint of the thumb may be indicated in Bennett's fracture, dislocation or ankylosis with deformity, or for arthrodesis of the joint in paralysis of the short muscles of the thumb.

A curved incision from 1½ to 2 inches long is made over the radiopalmar surface of the joint. It begins on the radial border of the thenar eminence medial to the abductor pollicis brevis muscle; from here it continues proximally to just below the level of the distal crease on the anterior surface of the wrist, then turns inward and parallels this crease for ¾ of an inch. The flap of skin and deep fascia is turned distally and medially. If necessary the superficial volar branch of the radial artery may be ligated. The abductor pollicis brevis muscle lies in the floor of the wound and the carpometacarpal joint is exposed by separating a part of its origin from the transverse carpal ligament and the greater multiangular bone. Free access is obtained by this approach.

VI. Approaches to the Metacarpophalangeal and Interphalangeal Joints. Operations upon the metacarpophalangeal joints are usually performed for fixed extension, the result of injury or infection. If motion in these joints is limited by soft part contractures, principally tight collateral ligaments, capsulotomy is the operation of choice. On each side of the affected joint, a lateral incision is made. The corresponding interosseous muscle is retracted and the capsule is exposed. The thickened collateral ligaments are completely excised in an elliptical fashion and the joint is then brought into flexion Simple division of the ligaments is not sufficient.

In bony ankylosis of the metacarpophalangeal joint arthroplasty may be performed through a dorsolateral incision centering over the joint. The joint is exposed between the dorsal aponeurosis and the interosseous muscle. Operation upon the metacarpophalangeal joint of the thumb may be indicated in dislocation and in malunited fractures. The joint may be exposed by incision over the radiopalmar border of the joint between the cutaneous branches of the radial and median nerves.

Approaches to the middle and distal interphalangeal joints should be from their lateral surfaces, the incisions centering over these joints. The corresponding volar digital vessels and nerves should be isolated and identified. In the fingers the nerves lie ventral to the arteries while in the palm the nerves are dorsal to the arteries.

III. Approach to the Radial Aspect of the Wrist Joint.

1. *Indications.* Ununited fractures of the scaphoid.

2. *Position of the Patient.* The position of the patient is the same as that used for both the ventral and dorsal approaches except that the forearm is held in the midposition with the radial aspect of the wrist uppermost.

3. *Landmarks.* (a) Lower end of the radius and radial styloid, (b) tendons forming the boundaries of the anatomic snuff-box.

4. *Incision.* A longitudinal incision, 3 inches long, is made over the snuff-box with its central point over the tubercle of the scaphoid. The radial artery and the lateral terminal branch of the radial nerve are identified and retracted to the palmar aspect of the incision together with the tendons of the abductor pollicis and extensor pollicis brevi muscles. The tendon of the extensor pollicis longus muscle is retracted to the ulnar side of the incision. In the floor of the wound the radial collateral ligament is incised and the scaphoid is exposed. Drilling and bone grafting operations on the scaphoid can be carried out through this approach. Great care must be used to avoid injury to the radial artery and the branches of the radial nerve which supply the skin of the radial aspect of the thumb.

IV. Approaches to the Ulnar Aspect of the Wrist.

A. Approach of Darrach.

1. *Indications.* (a) Fracture of the styloid process of the ulna or the triquetrum, (b) derangement of the inferior radio-ulnar joint, (c) arthrodesis of the wrist (*Smith-Petersen*).

2. *Position of the Patient.* The patient's arm is supported on an arm board in full pronation with the ulnar aspect of the forearm facing the surgeon.

3. *Landmarks.* (a) Lower end of the ulna, (b) styloid, (c) ulnar surface of the carpus

4. *Incision.* Darrach's operation was devised for derangement of the inferior radio-ulnar joint frequently caused by Colles' fracture, fractures of the shaft of the radius with overriding of the fragments, or for an unreduced dislocation of the wrist and deformity caused by injury to or disease of the lower radial epiphysis. In the writers' experience, the results with this operation have been excellent.

An incision is made longitudinally on the ulnar aspect of the forearm, extending from the tip of the ulnar styloid upward. It is carried down to the periosteum between the tendons of the flexor and extensor carpi ulnaris muscles. Care must be taken to avoid the dorsal branch of the ulnar nerve. The periosteum is then reflected from the lower portion of the ulna and the bone is cut across obliquely, leaving a sloping margin to the proximal fragment The lower fragment is then turned out of the wound and the attachment of the capsule can be divided close to the articular cartilage. The ulnar styloid is cut across at its base and left behind with the attachment of the collateral ligament. The periosteum is closed to provide stability.

B. Approach of Smith-Petersen Smith-Petersen used a similar approach for fusion of the wrist. The incision starts 2 or 2½ inches above the ulnar styloid running parallel with the ulna to a point just distal

and middle layers at the lateral margin of the quadratus lumborum muscle thus forming a fascial envelope for it. The latissimus dorsi muscle takes its lower origin from the posterior layer of the lumbodorsal fascia, and through it is attached to the spines of the lumbar and sacral vertebrae and the posterior iliac crest.

MUSCLES. The longitudinal group of erector spinae muscles arises, along with the posterior lamella of the lumbodorsal fascia covering it, from the sacrum, the vertebral spines and the inner lip of the posterior iliac crest. The quadratus lumborum muscle arises from the posterior iliac crest and iliolumbar ligament narrowing as it passes upward to insert in the twelfth rib. This fleshy mass fills the hollow between the posterior iliac crest and the spinous processes. The gluteus maximus muscle arises from the posterior gluteal line of the ilium, the posterior iliac crest, the surface of the lower sacrum and from the lumbodorsal fascia.

NERVES AND VESSELS The skin about the area of the sacroiliac joint is supplied by cutaneous branches of the rami of lumbar 1, 2, and 3 including the lateral cutaneous branch of the iliohypogastric. These nerves perforate the lumbodorsal fascia and extend downward across the posterior iliac crest to supply the skin of the buttocks.

No motor nerves or important vessels are necessarily divided in exposure of the sacroiliac joint. In stripping the gluteal muscles from the ilium, however, it is important to remember that the superior gluteal nerve and artery enter the region at the anterior-superior border of the sciatic notch and are susceptible to damage, especially if the fibers of the gluteus maximus are separated too far inferiorly.

SURGICAL APPROACHES TO THE SACROILIAC JOINT

I. Approach of Smith-Petersen

II. Approach of Key

The most commonly used approaches are those described by Smith-Petersen and Key. The indications and landmarks are the same for both. In the approach of Gaenslin, the posterior crest and posterior-superior spine of the ilium are exposed The posterior ilium is split vertically forming inner and outer leaves. A triangular piece of the inner leaf over the sacroiliac joint is removed thus exposing its cartilaginous surfaces. From the authors' experience they see no advantage of the Gaenslin technic over the approaches described by Smith-Petersen and Key. The method employed by Campbell for extra-articular fusion of the joint is not strictly speaking an approach to the sacroiliac joint and will, therefore, be omitted.

1. *Indications.* (a) Arthrodesis for tuberculosis, (b) instability, (c) chronic arthritis.

2. *Landmarks* (a) Posterior iliac crest, (b) posterior-superior and inferior iliac spines, (c) sacrum, (d) spinous processes of vertebrae, (e) anterior-superior spine of the ilium, (f) greater trochanter.

I. Approach of Smith-Petersen. The incision in the skin may be described as consisting of anterior and posterior portions which join at the posterior iliac spine From this bony landmark the anterior portion is

THE SACROILIAC JOINT

General Anatomic Considerations. The sacroiliac articulation is an amphiarthrodial joint between the articular surfaces of the sacrum and the ilium. It embraces the upper three segments of the sacrum. The joint space is an unevenly curved slit in an oblique vertical plane. The articular surface of the sacrum faces posteriorly and laterally to meet with the ilium. Each ear-shaped articular surface is covered by a thin plate of hyaline cartilage which is interspersed with patches of soft fibrocartilage. On the inner face of the ilium, above the joint and extending up to the posterior iliac crest, is a broad, roughened area, the iliac tuberosity, for the insertion of the sacroiliac ligaments. The upper margin of the greater sciatic notch is at the lower border of the joint. Anteriorly, bounded by the iliopectineal line, is the iliac fossa. Behind are the posterior-superior and posterior-inferior iliac spines and the notch between them. The sacrum presents the counterpart, an auricular surface with a roughened tuberosity above and behind. A short thin capsule connects the joint margins and contains the synovial fluid.

Three strong ligaments support the sacroiliac joint preventing all but the slightest motion. The most powerful ligament in the body, and nearly as large as the joint itself, is the interosseous sacroiliac ligament whose multitude of short tough fibers connect the tuberosities of the sacrum and the ilium above the joint. The anterior sacroiliac ligament covers the front of the joint, its many fibers passing transversely from the sacrum to the ilium. The posterior sacroiliac ligament lies in the deep depression between the sacrum and ilium behind. Its short fibers run horizontally, while the longer ones run obliquely to connect the posterior portion of the tuberosity of the ilium and the posterior-superior iliac spine to the first and to the fourth transverse tubercles of the sacrum. Posteriorly and more superficially, the sacrotuberous ligament serves as a strut to the joint arising broadly from the posterior-inferior iliac spine and the fourth and fifth tubercles of the sacrum to converge on the inner margin of the tuberosity of the ischium. The sacrospinous ligament, arising in front of the sacrotuberous ligament by a broad base converges similarly on the ischial spine. Above, the strong iliolumbar ligament stretches from the tip of the transverse process of the fifth lumbar vertebra to the iliac crest in front of the quadratus lumborum muscle.

Fascia. Beneath the skin posteriorly the lumbodorsal fascia covers the area widely. It forms the tendon of origin of the transversus abdominis muscle laterally, the fibers running medially to split into three layers, the posterior, middle and anterior lamellae respectively. The posterior lamella, by far the thickest and toughest, is attached to the lumbar vertebral spines, while the middle layer is attached to the posterior surfaces and tips of the lumbar transverse processes. These two fuse at the lateral margin of the erector spinae muscle to enclose it in a dense aponeurotic compartment. The anterior lamella, the thinnest, attaches to the anterior surfaces of the lumbar transverse processes and meets the fused aponeurosis of the posterior

The gluteus medius and gluteus maximus muscles lie in the floor of the wound with their line of separation running roughly parallel to the incision near its upper margin. These muscles are fused near their origin on the posterior iliac crest but can be separated in the lateral part of the wound.

The fascia and muscle origins on the inner and outer faces of the posterior iliac crest are cut so that the iliac origin of the gluteus maximus is incised along with about 2 inches of the posterior iliac origin of the gluteus medius. Key points out that, "the cutting of the fascia and origin of the muscle from the posterior part of the crest of the ilium is not a part of the arthrodesis but is done on the basis that this fascia may be a factor in causing the pain." The interval between the gluteus medius and gluteus maximus is then developed by blunt dissection. The superior gluteal vessels and nerve entering the field around the anterior-superior border of the sacrosciatic notch must be identified and protected. The gluteus medius is stripped from the ilium and retracted upward, while the gluteus maximus is similarly stripped and retracted downward to expose the bone between the posterior iliac crest and the sciatic notch. The upper margin of this notch lies just below and parallel to the skin incision. The area of posterior ilium which is thus laid bare overlies the sacroiliac joint.

A window is cut in the bone through the full thickness of ilium down to the sacroiliac joint. This permits removal of a plug of bone about 1½ inches wide on its posterior end and ¾ of an inch wide anteriorly which is approximately the size of the window cut by Smith-Petersen. This opening is then deepened into the sacrum and the exposed margin of the joint curetted. After being trimmed, the plug of bone is driven across the joint. Bone chips are raised to fill the window. The wound is closed in the usual fashion.

THE HIP JOINT

General Anatomic Considerations. The hip joint, an enarthrodial or ball and socket joint, is formed by the articulation of the head of the femur with the acetabulum. The acetabulum lies at the site of union of the ilium, ischium and pubis. Below, the bony socket is deficient in an area known as the acetabular notch. This notch is bridged by the transverse acetabular ligament and gives origin to the ligamentum teres. The bottom of the acetabulum, called the acetabular fossa, is thin, nonarticular and continuous with the notch. The socket is deepened by a cartilaginous rim, the glenoid labrum, which is attached along the periphery except at the notch and grasps the head of the femur beyond its equator. Within the pelvis, the origin of the levator ani divides the acetabulum. Hip joint infection breaking through the thin fossa can track either upward above the levator to cause intrapelvic and iliopsoas abscesses or downward below the muscle to form ischiorectal abscesses. The head of the femur is covered with cartilage except for a depression a little below and behind its center, an area called the fovea to which the ligamentum teres is attached.

The capsule is fibrous and heavy. It is attached proximally to the margin of the acetabulum, distally and anteriorly to the intertrochanteric line, and distally and posteriorly to the femoral neck at about its midportion.

curved forward along the crest of the ilium two thirds of the distance to the anterior-superior spine, while the posterior portion is made in a straight line downward and forward in the direction of the fibers of the gluteus maximus for a distance of 3 or 4 inches. The anterior part of the incision is carried down to the bone, and the reflection of the periosteum is started; then the posterior part is carried down through the subcutaneous fat and *gluteal fascia and the muscle fibers of the gluteus maximus are separated by* blunt dissection until the junction of the ilium and sacrum between the posterior-superior and posterior-inferior spines is reached. In carrying out this dissection, one point should be kept in mind: the superior gluteal nerve and the superior gluteal artery and veins emerge at the superior portion of the sacrosciatic notch and give off branches which disappear beneath the gluteus maximus and gluteus medius. The vessels sometimes cause considerable bleeding and may have to be sacrificed in order to get a satisfactory reflection. The flap thus outlined is reflected subperiosteally, which exposes the posterior portion of the lateral surface of the ilium.

Smith-Petersen states that, "if the sacroiliac joint is projected on the lateral surface of the ilium, it will be found that the inferior border corresponds with the upper margin of the sacrosciatic notch and the anterior border with the median gluteal line. The superior border is not of importance, because the two above landmarks determine the location of the joint sufficiently. A rectangular window is now cut through the ilium within the projected area of the joint extending posteriorly into the inferior sacroiliac ligament. The thickness of the ilium just above the sacrosciatic notch is considerable, sometimes as much as an inch, but if care is taken, the entire block of bone from the outer to the inner table of the ilium may be removed in one piece. The operator is rewarded for his labor when, upon removal of the window, the cartilaginous joint surface of the sacrum comes into view." This cartilage as well as its underlying cortex is excised to bring about a good exposure of cancellous bone of the sacrum. The cartilage and cortex are then removed from the block of bone and the remaining cancellous portion is replaced at its original site and countersunk across the joint line into the cancellous bone of the sacrum.

The flap is now returned to its place and periosteum and the soft parts are sutured in layers.

The position of the window should be varied according to the case encountered. To provide adequate drainage in purulent infections of the joint, the window is cut in a direction parallel to the sacrosciatic notch. In tuberculosis and where the operation is performed for relaxation of the sacroiliac joint, it is better to cut the window at an angle as a better dowel is obtained.

II. Approach of Key. The approach is made through a straight skin incision which is begun close to the midline over the sacrum at the level of a line joining the posterior-superior spines of the iliac and is extended downward and outward for about 6 inches ending just above the greater trochanter. The superficial fascia is incised, and the margins of the wound are dissected free from the thin fascia which covers the muscle to afford wide retraction. This exposes the posterior iliac crest and the posterior-superior and posterior-inferior iliac spines in the medial end of the wound.

The tendon of the psoas crosses the hip joint medial to the Y-ligament, thus reinforcing a weak point in the capsule.

Lateral and posterior to the tensor fasciae latae muscle is the gluteal area which contains the gluteus medius, minimus and maximus muscles. On the lateral surface of the ilium can be seen the posterior, anterior and inferior gluteal lines arising from the sciatic notch and curving forward crescentically. These lines outline the origins of the gluteus medius and gluteus minimus which cover the surface of the bone. These two muscles are inserted respectively into the anterior border and superior border of the greater trochanter.

Posteriorly, the gluteus maximus arises from the lower sacrum and upper coccyx, a small area on the ilium and the entire sacrotuberous ligament, and runs downward and laterally to its insertion. This insertion is of two kinds, fascial and bony The superficial fibers join the part of the iliotibial tract which slides on the greater trochanter; so, too, the upper half of the deep fibers; the lower half, however, implant themselves into the bone, marking the back of the femur and forming there the distal point of the gluteal parallelogram (Henry).

The gluteus medius and minimus muscles are supplied by the superior gluteal nerve, while the gluteus maximus is supplied by the inferior gluteal nerve.

On the posterior aspect of the hip beneath the gluteus maximus muscle and a generous layer of fat, the external rotators of the hip joint can be seen as they leave the greater sciatic notch to reach the buttock and posterior thigh. The external rotator muscles of the hip are the piriformis, the obturator internus, the superior and inferior gemelli, the obturator externus and the quadratus femoris. They are inserted into the trochanter and intertrochanteric fossa. The piriformis muscle is an important surgical landmark, since all vessels and nerves leaving the pelvis to enter the gluteal region pass out through the greater sciatic foramen above or below the piriformis. Above the piriformis are the superior gluteal vessels and superior gluteal nerve, while below this muscle, from the outside in, are the sciatic nerve, the nerve to the quadratus femoris, the inferior gluteal nerve, the posterior cutaneous nerve of the thigh, the inferior gluteal artery, the nerve to the obturator internus and the internal pudendal vessels and nerves. They lie upon the obturator, the gemelli and quadratus femoris muscles.

Nerves. The cutaneous nerves of surgical importance about the hip joint are the lateral femoral cutaneous nerve, the posterior cutaneous nerve of the thigh and lateral cutaneous branch of the iliohypogastric. The lateral femoral cutaneous nerve passes beneath the inguinal ligament just medial to the anterior-superior spine of the ilium, crosses the sartorius muscle and divides into anterior and posterior branches which supply the lateral surface of the thigh almost to the knee. It is a useful guide to the interval between the tensor fasciae femoris and the sartorius in anterior approaches to the hip joint.

The posterior cutaneous nerve of the thigh, also termed the small sciatic nerve, enters the region at the lower border of the piriformis. It descends beneath the inferior border of the gluteus maximus with the inferior gluteal artery; then it passes down the back of the thigh under

The outer half of the femoral neck and the posterior surface of the greater trochanter are, therefore, extracapsular, a point of practical importance to the surgeon. The capsule is reinforced anteriorly by the strong iliofemoral ligament, the Y-ligament of Bigelow, which is intimately blended with the capsule. The stem of the Y-shaped portion is attached above to the antero-inferior iliac spine. The two limbs of the Y pass downward to blend with the capsule at the upper and lower parts of the intertrochanteric line. The Y-ligament is useful as a lever in manipulations for reduction of dislocations of the hip and in fractures of the neck of the femur. The synovial membrane covers the deep surface of the capsule, the femoral neck and the circumference of the ligamentum teres, which is extrasynovial. Two out-pocketings of the synovium through the capsule may sometimes connect with the bursa for the tendon of the obturator externus posteriorly and the bursa for the tendon of the iliopsoas anteromedially.

The chief blood supply to the head and neck of the femur, aside from what may be supplied through the ligamentum teres by a branch of the obturator artery, comes from branches of the medial femoral circumflex and the superior and inferior gluteal arteries which enter the neck through the posterior capsule. To avoid injuring them, therefore, the surgeon should limit his stripping of the capsule and periosteum in this region.

The nerve supply of the hip joint is obtained from the femoral, obturator and sciatic nerves. Pain from the hip is usually referred down the inner aspect of the thigh to the knee along the course of the obturator nerve, but it may also be referred to the anterior surface of the thigh over the distribution of the femoral nerve.

The deep fascia of the thigh invests the muscles of the hip and thigh and preserves their contours. Laterally it is thickened and almost tendinous where it receives the insertions of the tensor fasciae latae and the gluteus maximus. This thickened portion, the iliotibial tract, takes origin on the anterior iliac crest and inserts into the lateral condyle of the tibia and the head of the fibula.

Muscles The tensor fasciae femoris and sartorius muscles arise from the anterior iliac crest and anterior-superior iliac spine respectively. Passing down the thigh, they diverge to form the outer and inner borders of a triangle which is an important surgical landmark for anterior approaches to the hip. The floor of this triangle is formed by the straight and reflected heads of the rectus femoris and the upper portion of the vastus lateralis muscles. The straight head of the rectus arises from the anterior-inferior iliac spine, while the reflected head takes origin from the groove on the middle of the superior border of the acetabulum. The vastus lateralis, the largest part of the quadriceps, arises from the femur by a broad aponeurosis which is attached laterally to an area on the femur just below the greater trochanter and anteriorly to the intertrochanteric line.

The tensor fasciae femoris is enveloped by two layers of the fascia lata. From the deep layer a band of fascia extends downward and medially to blend with the capsule of the hip joint. This is a surgical guide to the joint. At the medial border of the triangle referred to above, directly beneath the sartorius, the outer part of the iliopsoas formed by the iliacus and psoas muscles passes toward its insertion into the lesser trochanter.

the inguinal ligament and descends medial and then posterior to the femur. It gives off the lateral and medial circumflex arteries. The lateral circumflex passes outward under the rectus to divide into ascending, transverse and descending branches. The ascending branches pass upward beneath the tensor fasciae femoris to anastomose in the neighborhood of the anterosuperior and anteroinferior spines of the ilium as described. The transverse branch passes backward over the vastus lateralis to the posterior surface of the greater trochanter where it takes part in the cruciate anastomosis with the medial circumflex, the inferior gluteal vessels and the ascending branch of the first perforating artery from the profunda. The descending branch of the lateral circumflex artery accompanies the nerve of supply to the vastus lateralis. In enlargement of the operative wound inferiorly, and when division of the fascial insertion of the tensor fasciae femoris is contemplated, this nerve and vessel should be identified.

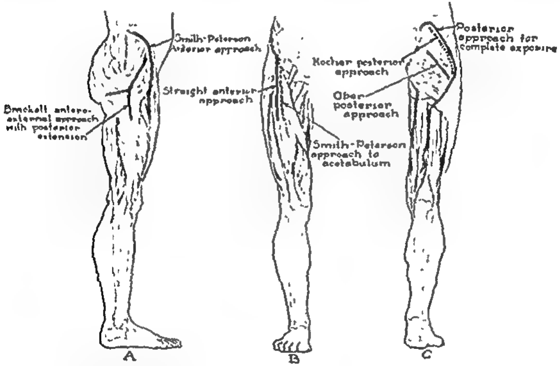

Fig. 13-25. Skin incisions of the commonly used approaches to the hip joint. (Courtesy Dr. LeRoy C. Abbott and associates.)

The superior gluteal artery arises from the hypogastric artery and escapes from the pelvis through the sciatic notch above the piriformis. Immediately after its exit, it divides into superficial and deep branches. The superficial branch is distributed to the deep surface of the gluteus maximus and is placed between it and the gluteus medius. The deep division bifurcates close to its origin into the superior and inferior branches. Both of these lie between the gluteus medius and minimus muscles. The superior branch follows the anterior curved line of the dorsum ilii, and at the anterior spine terminates by anastomosing with the superficial and deep circumflex iliac arteries and the ascending branch of the lateral circumflex artery. The inferior branch runs distally and anteriorly toward the greater trochanter giving twigs to the gluteus medius and minimus and some to the hip joint (Fig. 13-25).

the fascia lata to provide sensation to the skin of the gluteal region and posterior thigh. The nerve is a valuable guide to the sciatic nerve and other structures emerging from the greater sciatic notch.

The lateral cutaneous branch of the iliohypogastric nerve arises from the first lumbar nerve, pierces the external oblique muscle posteriorly just above the iliac crest and is distributed to the skin of the gluteal region. In posterior approaches to the hip or sacroiliac joints its preservation prevents the occurrence of an undesirable area of anesthesia over the buttock. It is often accompanied by a large vessel which may require ligation to prevent troublesome hemorrhage.

The major mixed nerves which may require identification in approaches to the hip are the obturator, the femoral and the sciatic. The obturator nerve enters the thigh medially through the upper part of the obturator foramen and then divides into its two major branches which pass anteriorly and posteriorly to the adductor brevis muscle. They are seen in the anterior medial approach to the hip which is occasionally employed. The femoral nerve enters the thigh under the inguinal ligament lateral to the femoral artery and vein. It is separated from the vessels by the femoral sheath which is formed by the transversalis fascia anteriorly and the iliac fascia posteriorly. The nerve breaks up immediately into motor and sensory divisions for supply of the muscles and skin of the anterior thigh. In the anterior approach to the hip joint now used by Smith-Petersen the nerve to the rectus requires identification and protection.

The sciatic nerve, the most lateral of the structures entering the gluteal region at the lower margin of the piriformis, passes distally midway between the ischial tuberosity and the greater trochanter. At the lower border of the gluteus maximus the nerve becomes subfascial and can be seen in the angle formed by this muscle and the lateral border of the common origin of the hamstrings. All of its branches to the hamstrings except that to the short head of the biceps arise from its medial surface, and thus it may be retracted inward with safety.

The gluteal musculature is supplied by the gluteal nerves. The superior gluteal nerve, leaving the pelvis through the greater sciatic notch above the piriformis, divides into a superior and inferior branch. The superior branch goes to the gluteus minimus, while the inferior branch, passing forward between the medius and minimus, gives branches to both muscles and ends by supplying the tensor fasciae femoris. The inferior gluteal nerve leaves the pelvis at the lower border of the piriformis and divides into branches to innervate the gluteus maximus. These nerves are accompanied by the corresponding gluteal vessels.

Vessels. The femoral triangle is bounded by the sartorius laterally, the adductor longus medially and the inguinal ligament superiorly. The femoral artery and vein bisect the triangle. Just above and below the inguinal ligament the deep and superficial circumflex vessels arise from the external iliac and femoral arteries respectively. They pass outward to the region of the anterior-superior spine of the ilium where they anastomose with terminal branches of the superior gluteal and ascending branches of the lateral circumflex arteries. The profunda femoris artery usually arises from the lateral side of the *femoral* artery *in the femoral triangle* 1½ inches below

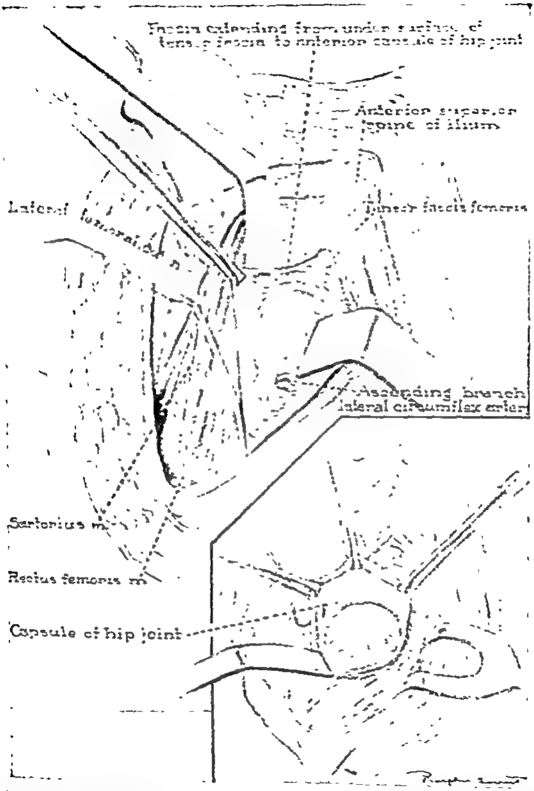

Fig. 13-26. Straight anterior approach to the left hip through the interval between the sartorius and rectus femoris medially and the tensor fasciae femoris and gluteus medius laterally. (Courtesy Dr. LeRoy C. Abbott and associates.)

SURGICAL APPROACHES TO THE HIP JOINT

I. Approaches to the Anterior Aspect of the Hip Joint
  A Straight Anterior Approach (Heuter-Schede)
  B Anterior Iliofemoral Approach (Smith-Petersen)
  C. Anterior Approach for Acetabuloplasty and Arthroplasty (Smith-Petersen)

II. Approaches to the Lateral Aspect of the Hip Joint
  A. Anterolateral Approach (Brackett, Watson-Jones)
  B Straight Lateral Approach
  C. U-shaped Approach with Osteotomy of the Greater Trochanter

III. Approaches to the Posterior Aspect of the Hip Joint
  A Posterolateral Approach (Kocher)
  B Posterior Approach (Ober)
  C Complete Posterior Exposure

I. Approaches to the Anterior Aspect of the Hip Joint (Fig. 13-26).

A. STRAIGHT ANTERIOR APPROACH.

1. *Indication.* Arthrotomy for limited exposure of the anterior aspect of the joint, head and neck of the femur.

2. *Position of the Patient.* The patient is supine with the hip near the edge of the table.

3. *Landmarks.* (a) Anterior-superior iliac spine, (b) sulcus between the sartorius and tensor fasciae femoris, (c) greater trochanter.

4. *Incision* The incision begins at the anterior-superior iliac spine and extends straight down the anterior aspect of the upper thigh for about [illegible] inches. The deep fascia is incised longitudinally and the interval is found between the sartorius and tensor fasciae femoris muscles. The lateral femoral cutaneous nerve is isolated and protected by retracting it medially. With retraction of the sartorius medially and the tensor fasciae femoris laterally, the rectus femoris muscle is seen. At this stage of the dissection it may be necessary to ligate the anastomosing vessels in the region of the anterior-superior and anterior-inferior spines referred to in the anatomic description. The direct and indirect head of the rectus femoris are dissected free from the underlying capsule to permit incision of the latter structure and exposure of the joint. Greater access can be secured by dividing the direct head of the rectus ½ inch below its origin from the anterior-inferior spine of the ilium and retracting it laterally.

This approach provides a limited exposure of the anterior aspect of the hip joint. Excellent approaches for major operations on the hip joint have been devised by Smith-Petersen

B. THE ANTERIOR ILIOFEMORAL APPROACH. This approach was originally described by Smith-Petersen as: *A New Supra-Articular Subperiosteal Approach to the Hip Joint.* Recent changes in both the iliofemoral and anterior approaches which have been made by Smith-Petersen have been sent to the senior author and will appear in quotations.*

1. *Indications.* (a) Arthrodesis of the hip, (b) congenital dislocation, (c) fracture of the neck of the femur.

* The authors wish to express their appreciation for Dr M. N. Smith-Petersen's permission to quote directly from his personal communications concerning these two most valuable approaches to the hip joint.

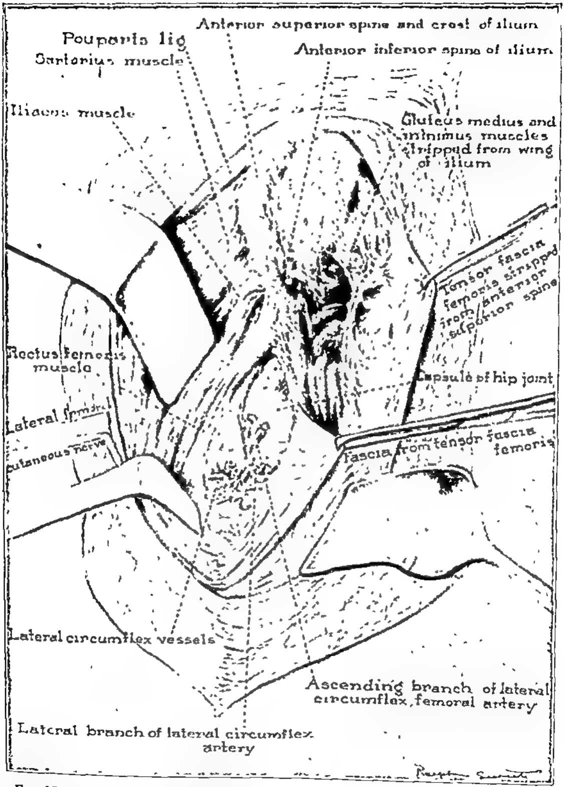

Fig. 13-27. Anterior iliofemoral approach (Smith-Petersen) The musculature is stripped subperiosteally from the outside of the wing of the ilium. The origin of the rectus femoris is delineated and the ascending branches of the lateral circumflex femoral vessels are ligated. (Courtesy Dr. LeRoy C. Abbott and associates.)

2 *Landmarks.* (a) Anterior-superior spine of the ilium, (b) anterior one third of the crest of the ilium, (c) interval between the sartorius and the tensor fascia femoris, (d) greater trochanter.

3. *Position of the Patient.* The patient is supine turned toward the sound side with the affected hip supported on sandbags.

4. *Incision.* The anterior part of the incision extends from the anterior-superior spine of the ilium downward along the anterior border of the tensor fasciae femoris to below the level of the greater trochanter. The tensor fasciae femoris and sartorius muscles are separated for exposure of the anterior capsule of the joint in a similar manner to that described under the straight anterior approach to the joint. The anterior incision is joined by a curved incision along the crest of the ilium which passes between the origins of the gluteus medius and tensor fascia femoris inferiorly and the external oblique superiorly. The flap outlined by these two incisions is freed from the ilium by subperiosteal dissection; the extent to which the flap is reflected posteriorly depends upon the individual case (Fig. 13-27). By reflecting the origin of the tensor fasciae femoris with the flap, the superior gluteal nerve and artery are preserved. The capsule is opened on its superior surface with preservation of the Y-ligament of Bigelow. "At present I excise most of this ligament with the anterior capsule. The capsule is freed posteriorly along the cotyloid ligament to give the desired exposure."

In closing, the flap is turned back and the anterior limb of the incision is closed in layers The curved limb of the incision is closed by suturing the periosteal origin of the gluteus medius and tensor fasciae femoris muscle to the external oblique and its overlying fascia.

To expose the lateral surface of the greater trochanter for insertion of the three flanged nail in some of his earlier cases of fracture of the neck of the femur, Smith-Petersen divided obliquely a part of the iliotibial tract below the insertion of the tensor fasciae femoris. This procedure avoided the necessity of a second incision over the greater trochanter. The partially divided iliotibial tract was repaired by interrupted sutures.

C. Anterior Approach of Smith-Petersen.

1. *Indications.* This approach was developed by Smith-Petersen for operations of acetabuloplasty and arthroplasty. It may be used for arthrodesis, for the reduction of slipped upper femoral epiphysis and for congenital dislocation of the hip.

2. *Position of the Patient.* The patient is supine with a sandbag under the affected hip.

3. *Landmarks.* (a) Anterior-superior iliac spine, (b) anterior iliac crest, (c) sulcus between the sartorius and the tensor fasciae femoris, (d) greater trochanter.

4. *Incision.* The incision extends along the anterior third of the iliac crest to the anterior-superior spine and then curves slightly to follow the lateral border. "I now follow the anterior border of the tensor as I did in my original incision. By so doing, I am often able to preserve the thin fascial compartment of the sartorius; this protects the sartorius and diminishes the trauma of retraction" Immediately inferior to the anterior-superior spine of the ilium the interval between the sartorius and the tensor

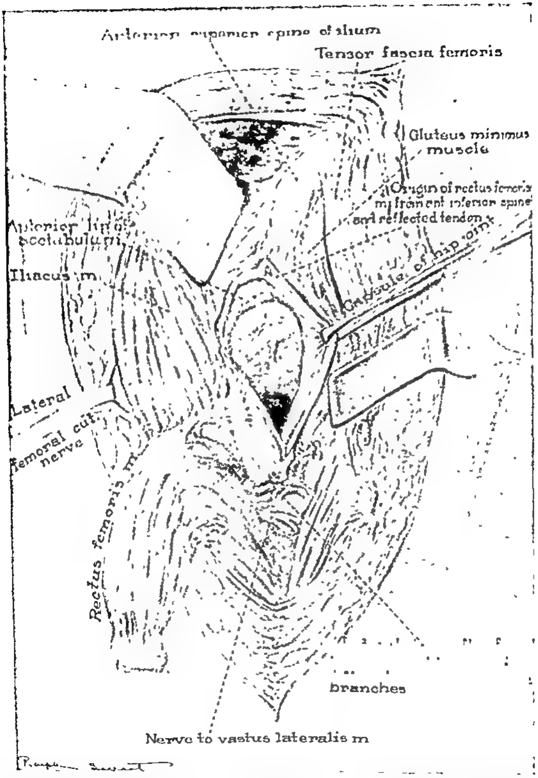

Fig. 13-28 Anterior approach for acetabuloplasty or arthroplasty (Smith Petersen). Drawn from an anatomic dissection on the left hip The direct head of the rectus has been severed and the muscle has been retracted much further distally than is done at operation (see recent comment in text by Smith-Petersen) (Courtesy Dr LeRoy C. Abbott and associates.)

fasciae femoris is exposed by dividing the deep fascia. Deep in this interval the direct head of the rectus femoris and its origin from the anterior-inferior spine is found by sharp dissection. Mesial to and below the anterior-superior spine, the lateral femoral cutaneous nerve will often be seen. Thus far the approach resembles the straight anterior approach. From here on, however, the exposure of the deeper structures is greatly facilitated by the following steps (Fig. 13-28): First, the direct head of the rectus is sectioned about a half-inch distal to its origin from the anterior-inferior spine of the ilium and at its junction with the indirect head. "I now divide the direct head of the rectus close to the anterior-inferior iliac spine, without leaving any stump. My reason for this is that the stump sometimes becomes calcified and scarred to such an extent that it interferes with flexion. Furthermore, I now sacrifice the inferior half of the inferior spine." To permit of its free retraction downward and laterally, its nerve supply from the femoral nerve is identified in the fascia overlying the iliopsoas muscle. "I now try to keep the rectus femoris in its sheath—I do not free it laterally—I simply free it by blunt dissection from the main portion of the iliacus; the acetabular origin of the iliacus, which almost embraces the tendon of the rectus, is reflected with the rectus. In doing this reflection I use an angulated knife blade that allows me to cut parallel to the anterior surface of the hip joint, —I unquestionably get some of the Y-ligament of Bigelow which tends to make the posterior aspect of the flap stronger and protects the posterior aspect of the rectus tendon and the rectus belly." Secondly, the origin of the tensor fasciae femoris from the ilium is freed subperiosteally in whole or in part as the individual case demands. "The tensor fasciae femoris is always reflected along with the very anterior portion of the gluteus medius." Thirdly, the iliacus is dissected subperiosteally from the medial surface of the ilium and the superior ramus of the pubis and its lateral border is followed to the insertion of the iliopsoas tendon into the lesser trochanter of the femur. In carrying out this step the bundle of nerves from the femoral nerve which supplies the sartorius and the rectus femoris must be protected and retracted mesially and inferiorly. "The inferior origin of the iliacus muscle, from the iliac fossa, is on a level with the middle of the anterior inferior iliac spine. Below this inferior origin there is a fat compartment, between the periosteum and the iliacus muscle. I, therefore, stop the reflection of the periosteum at the inferior margin of the origin of the iliacus and then use scissors dissection to separate the posterior aspect of the iliacus from the periosteum, that is, in the fat compartment. By so doing you can get a good look at the periosteum and you can very often see the periosteal branch of the deep circumflex iliac artery. I am apt to put a snap on it and coagulate it,—it doesn't as a rule need tying." The lesser trochanter is then osteotomized and this gives complete relaxation of the iliopsoas muscle and permits of its retraction inward. "I excise the lesser trochanter when I do a modified Colonna, and in old congenital hips with a high dislocation. In a modified Colonna I do it because the lesser trochanter gets too close to the region of the cotyloid notch. In congenital hip dislocations I do it because it is necessary in order to get sufficient downward displacement of the femoral head." This gives complete exposure of the anterior capsule of the hip joint and the superior,

insertions attached to it. This exposes the attachment of the capsule at the base of the femoral neck which can then be followed upward to the rim of the acetabulum. The capsule is divided on its superior aspect by an incision appropriate for the individual case.

B. The Straight Lateral Approach. This approach is not of sufficient importance to warrant its description here.

C. U-shaped Lateral Approach.

1. *Indications.* This approach has been used for anthrodesis and arthroplasty. In the writers' opinion it is inferior to the anterior approach of Smith-Petersen for these procedures.

2. *Position of the Patient.* The patient lies on the unaffected side with the knee flexed to a right angle. The hip to be operated upon is uppermost.

3. *Landmarks.* (a) Anterior-superior iliac spine, (b) greater trochanter, (c) posterior-superior iliac spine, (d) shaft of the femur.

4. *Incision.* A U-shaped incision is made from just below the anterior-superior spine of the ilium downward and backward across the base of the greater trochanter and then upward to the posterior-superior iliac spine. The fascia is incised over the interval between the lower portions of the gluteus medius and tensor fasciae femoris muscles, and they are separated down to the level of the lateral surface of the greater trochanter. The fascia lata is then divided transversely which exposes the posterior border of the greater trochanter. The interval between the gluteus maximus and gluteus medius is then developed posteriorly and the insertion of the gluteus minimus anteriorly is identified. This marks the level of the junction of the greater trochanter with the base of the neck of the femur.

The greater trochanter with its muscle insertion preserved is then cut through obliquely at its base with an osteotome, care being taken to make the osteotomy high enough to avoid injury to the base of the neck of the femur. The trochanter is then levered backward and upward with the attached piriformis, obturator, gemelli and gluteal muscles to expose the attachment of the capsule at the base of the femoral neck, its superior surface and the superior margin of the acetabulum. The capsule is opened by a vertical or transverse incision or a combination of both. Care should be taken to avoid injury to the capsular vessels on the posterior and posterior-superior surfaces of the neck of the femur.

Closure is effected by reattachment of the trochanter.

III. **Approaches to the Posterior Aspect of the Hip Joint.**

A. Posterolateral Approach (Kocher).

1. *Indications.* (a) Excision of the head of the femur, (b) drainage of a septic joint, (c) reduction of posterior dislocation of the hip, (d) fracture of the superolateral margin of the acetabulum.

2. *Position of the Patient* The patient is nearly prone but turned slightly to the well side with the hip to be operated upon supported by sandbags.

3. *Landmarks.* (a) Posterior-superior iliac spine and posterior portion of the iliac crest, (b) upper shaft of the femur and greater trochanter, (c) tuberosity of the ischium.

4. *Incision.* The Kocher incision is angular with upper and lower segments. The upper segment corresponds to the lower two thirds of a line joining the posterior-superior spine of the ilium and the prominence

mesial and inferior borders of the acetabulum as far as the cotyloid notch. The inner wall of the true pelvis overlying the floor of the acetabulum is also accessible. In some cases to permit of even greater access to the joint, a portion of the lateral border of the iliacus muscle which overlies the superior ramus of the pelvis and the anterior aspect of the capsule should be excised.

Since the appproach follows structural planes the closure is simple. "The direct head of the rectus femoris is sutured to the tendon of the reflected head, if this remains fairly well intact. If not, the rectus is sutured to the tendinous portion of the gluteus minimus. The external abdominal oblique with its overlying fascia is sutured to the gluteal fascia and periosteal origin of the gluteus medius and tensor fasciae femoris; the sartorius is sutured to the anterior border of the tensor fasciae femoris."

II. Approaches to the Lateral Aspect of the Hip Joint.

A. Anterolateral Approach (Brackett, Watson-Jones).

1. *Indications.* (a) Cervical and intertrochanteric osteotomy, (b) open reduction for fractures of the neck of the femur and for slipped upper femoral epiphysis.

2. *Position of the Patient.* The patient is supine with the affected hip elevated by a sandbag.

3. *Landmarks.* (a) Anterior border of the greater trochanter, (b) shaft of the femur, (c) anterior-superior iliac spine.

4. *Incision.* An oblique incision is made beginning at a point 1 inch posterior to the anterior-superior spine of the ilium and extending downward and backward to the middle of the lateral surface of the greater trochanter. The incision is then continued distally for from 2 to 3 inches, paralleling the anterior surface of the femur. The interval between the tensor fasciae latae and gluteus medius is found in the lower portion of the incision. Brackett recommended seeking the interval midway between the anterior-superior spine and the trochanter before the tensor fasciae latae begins to blend with its fascial insertion. The coarse grain and the direction of the fibers of the gluteus medius readily distinguish them from the fine structure of the tensor fasciae latae. These muscles are separated and the dissection is carried upward to expose the inferior branch of the superior gluteal nerve, the nerve of supply to the tensor fasciae femoris. This exposes the anterior part of the capsule overlying the outer part of the femoral neck, the anterior margin of the trochanter, the anterior and upper edges of the acetabulum and the tendons of origin of the rectus femoris muscle. The capsule can be opened by a vertical, transverse or curved incision.

This approach may be enlarged by making an incision for a distance of 2 or 3 inches directly backward at the junction of the oblique and vertical incisions. Through this incision the fascial insertion of the gluteus maximus muscle is cut and the posterior border of the greater trochanter is seen. With an osteotome the trochanter is then sectioned obliquely on a level with the base of the neck. This preserves the insertion of the gluteus minimus, gluteus medius and piriformis into the trochanter, and does not encroach upon the substance of the neck itself, thus preserving its strength. The trochanter is then levered posteriorly and superiorly with these muscle

to the posterior capsule is made by cutting the piriformis tendon and retracting it medially. If necessary, all the external rotators may be freed from their insertions (into the trochanter and trochanteric fossa) and retracted medially. The capsule is then incised as indicated in the individual case.

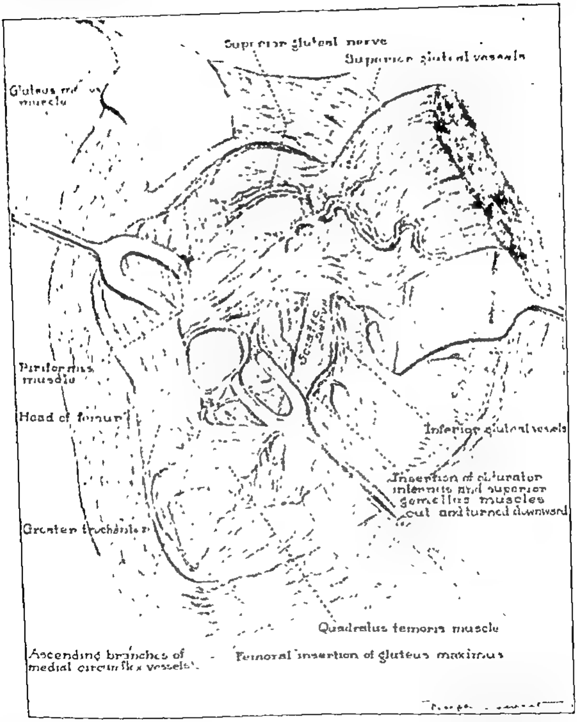

Fig 13-29. The approach for complete exposure of the posterior aspect of the left hip Capsule of the joint and the head and neck of the femur are exposed by detachment of the insertions of the obturator internus and gemelli and by reflecting them inward and downward (Courtesy Dr. LeRoy C Abbott and associates)

C. Complete Exposure of the Posterior Aspect of the Hip Joint (Fig. 13-29). The surgical anatomy and details of his method for exposure of the buttock, with illustrations, are given by Henry in his recent book

on the lateral surface of the greater trochanter; the lower segment extends vertically downward over the lateral surfaces of the greater trochanter and upper femur. Through the lower segment the iliotibial tract is split vertically while through the upper segment the fibers of the gluteus maximus are separated from below upward. In this separation of the fibers of the gluteus maximus muscle, branches of the superior and inferior gluteal vessels will require ligation, and at the upper angle of the wound the fibers of this muscle should be spread cautiously to avoid injury to the main divisions of these vessels. These divisions are often of considerable size and if they are damaged severe hemorrhage may occur.

A large angular flap consisting of skin, fascia and gluteus maximus is now turned medially; this exposes the posterior border of the gluteus medius and the piriformis muscles. The tendons of insertion of these two muscles and of the obturator internus into the trochanter and trochanteric fossa respectively are now turned forward by subperiosteal reflection. The posterior and superior surfaces of the capsule of the joint, the lateral part of the neck of the femur and the intertrochanteric fossa are now seen. With incision of the capsule, the head and neck of the femur and the posterior margin of the acetabulum are exposed. The head of the femur may be removed to provide drainage in severe sepsis of the joint; arthrodesis or even arthroplasty can be done through this approach though it does not afford the extensive exposure that is provided when the entire gluteus maximus is turned medially. The objection to this approach is the bleeding that may occur with separation of the fibers of the gluteus maximus muscle, particularly if this separation is carried too high. Furthermore, in separation of this muscle too far proximally there is danger of injury to the sciatic nerve. In adults this exposure may be enlarged by osteotomy of the greater trochanter which is then turned forward with the insertions of the gluteus medius and minimus muscles.

B. Posterior Approach of Ober.

1. *Indication.* Drainage of a septic hip joint.

2. *Position of the Patient.* The patient is in the prone position.

3. *Landmarks.* (a) Posterior-superior iliac spine, (b) posterosuperior angle of the greater trochanter.

4. *Incision.* The incision is made over the midportion of the gluteus maximus centering over the neck of the femur. It begins below the posterosuperior iliac spine and extends in the line of the muscle fibers to the posterosuperior angle of the greater trochanter where it may be curved distally along the posterior border of the trochanter if the exposure needs to be enlarged. The fibers of the gluteus maximus muscle are separated by blunt dissection until the layer of fat and areolar tissue beneath it is seen. The sciatic nerve is isolated in the upper, inner angle of the wound and protected throughout the operation The fat and areolar tissue in the floor of the wound are separated with care to avoid injury to the vessels which anastomose in this region. The piriformis muscle is found running parallel to the line of the incision, and just above it the posterior border of the gluteus medius is seen Below the piriformis the obturator internus, the gemelli and the quadratus femoris, in the order named, are identified. These muscles may be displaced downward while the approach

the large branches of the gluteal vessels which enter its deep surface. In this manner the external rotator muscles of the hip are seen with all of the structures which emerge from the sciatic notch above and below the piriformis. Henry points out that often a deep fold in the gluteus medius marks off a segment of this muscle which may be mistaken for the piriformis. As he points out, "A transverse plane grazing the top of the greater trochanter is at the caudal edge of the piriformis—a muscle sometimes fused above with the gluteus medius and minimus."

The posterior capsule of the hip joint can now be fully disclosed by subperiosteal detachment of the external rotators by beginning above with the insertion of the piriformis to the mesial surface of the anterior portion of the greater trochanter and continuing downward over the intertrochanteric fossa to free the gemelli, obturator internus and obturator externus. These muscles are then reflected inward with exposure of the outer posterior surface of the neck of the femur, the posterior capsule and the posterosuperior margin of the acetabulum. Appropriate incision in the capsule gives adequate vision of the acetabulum, and the head and neck of the femur.

Repair is then secured by interrupted sutures to the fascia and tendinous structures, special care being taken to close the fibrous covering of the adjacent margin of the gluteus maximus and gluteus medius muscles, the iliotibial tract and the bone insertions of the gluteus maximus muscle.

THE KNEE JOINT

General Anatomic Considerations. CAPSULE. The capsule is often described as a continuous structure of fibers, completely investing the joint; whereas the true fibrous portion of the capsule exists only on its posterior aspect where it extends from the proximal margin of the articular surface of the femur and intercondylar line to the posterior border of the head of the tibia. In contradistinction to the posterior part of the capsule, the anterior portion is ill defined. It is composed of the quadriceps tendon, the patella, the infrapatellar tendon and the blending of the fascia lata with the fibrous aponeuroses of the vasti muscles.

The quadriceps tendon is subdivided into three parts, readily discernible in a sagittal section through the middle of the patella. The anterior subdivision is the tendon of insertion of the rectus femoris, while the intermediate subdivision is the common tendon of the vastus medialis and the vastus lateralis, and the posterior subdivision is the tendon of the vastus intermedius (Fig. 13-30). The genu articularis muscle joins the tendon of the vastus intermedius and also provides a slip which inserts into the apex of the suprapatellar synovial pouch. Between the adjacent margins of the vasti, a fascial sling is formed which acts as a hammock or cradle for the tendon of the rectus femoris. This sling, traced laterally, blends with the aponeuroses of the vasti muscles. The aponeurosis at the lower margin of the vastus medialis divides into two distinct layers over the anteromedial aspect of the knee. The anterior layer passes across the patella in the form of a continuous sheet which blends with the aponeurosis of the vastus lateralis. Below the level of the tibial tubercle it becomes continuous with the deep fascia of the leg. The posterior or deep layer of the aponeurosis of

entitled *Extensile Exposure*. The writers have adopted Henry's method of approach for exposure of the posterior aspect of the hip joint.

1. *Indications*. Fracture of the posterior rim of the acetabulum and posterior aspect of the head of the femur.

2. *Position of the Patient*. The patient is in the prone position.

3. *Landmarks*. (a) Posterior-superior spine of the ilium, (b) posterior half of the crest of the ilium, (c) a point midway between the front and back edges of the greater trochanter, (d) a similar point on the femoral shaft level with the gluteal fold, (e) a point on the back of the thigh midway between the ischial tuberosity and the greater trochanter just below the gluteal fold.

4. *Incision*. The incision is shaped like a question mark and is started at the posterior-superior spine of the ilium and carried forward along the iliac crest for a hand's breadth. From here it is turned downward and outward across the buttock to the top of the greater trochanter; then it continues straight downward over the middle of the lateral surface of the greater trochanter and upper shaft of the femur to the level of the gluteal fold. The incision is then turned transversely to the middle of the posterior thigh. From here the stem of the question mark is formed by a vertical incision down the middle of the posterior surface of the thigh for a variable distance depending upon the extent of the exposure desired. The operation is now carried out by exposing the structures in the following order: posterior cutaneous nerve of the thigh (the small sciatic nerve), the insertion of the gluteus maximus into the femur and the iliotibial tract, the upper margin of the gluteus maximus muscle, and finally the bony insertion of the gluteus maximus into the posterior surface of the femur. In this way the borders of the "gluteal lid" (an appropriate term used by Henry) can be exposed and made ready to turn inward.

The posterior cutaneous nerve of the thigh lies just beneath the deep fascia and is exposed by a vertical division of this fascia in the stem of the question mark. The nerve is then traced upward to the lower border of the gluteus maximus. The lower border of this muscle is followed to its insertion into the iliotibial tract. This tract is divided vertically over the middle of the lateral surface of the bone until the tip of the greater trochanter is exposed. The fascia covering the gluteus medius posteriorly is exposed and by extending the cut upward a short distance above the tip of the trochanter the finger can be placed in a shallow cavity which marks the upper part of the insertion of the gluteus maximus into the iliotibial tract. The fibrous covering overlying the junction of the superior border of the gluteus maximus and the posterior border of the gluteus medius is then divided to the crest of the ilium. In this region the gluteus medius is not intimately attached to the fascia. A part of the origin of the gluteus maximus from the posterior crest of the ilium is incised and the adjacent portion of the lateral surface of the ilium is freed by subperiosteal reflection.

In the lower part of the wound the posterior cutaneous nerve of the thigh is protected and the bony insertion of the gluteus maximus is sectioned. Pressure should be used to control hemorrhage during this step The entire gluteus maximus is now turned inward with due care to protect

the large branches of the gluteal vessels which enter its deep surface. In this manner the external rotator muscles of the hip are seen with all of the structures which emerge from the sciatic notch above and below the piriformis. Henry points out that often a deep fold in the gluteus medius marks off a segment of this muscle which may be mistaken for the piriformis. As he points out, "A transverse plane grazing the top of the greater trochanter is at the caudal edge of the piriformis—a muscle sometimes fused above with the gluteus medius and minimus."

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THE KNEE JOINT

General Anatomic Considerations. Capsule. The capsule is often described as a continuous structure of fibers, completely investing the joint; whereas the true fibrous portion of the capsule exists only on its posterior aspect where it extends from the proximal margin of the articular surface of the femur and intercondylar line to the posterior border of the head of the tibia. In contradistinction to the posterior part of the capsule, the anterior portion is ill defined. It is composed of the quadriceps tendon, the patella, the infrapatellar tendon and the blending of the fascia lata with the fibrous aponeuroses of the vasti muscles

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the vastus medialis is inserted into the medial border of the patella and the upper margin of the tibia. The synovial membrane lies behind this layer. On the outer aspect of the knee, the deep fascia and aponeurosis blend to form a single layer which is inserted into the lateral margin of the patella

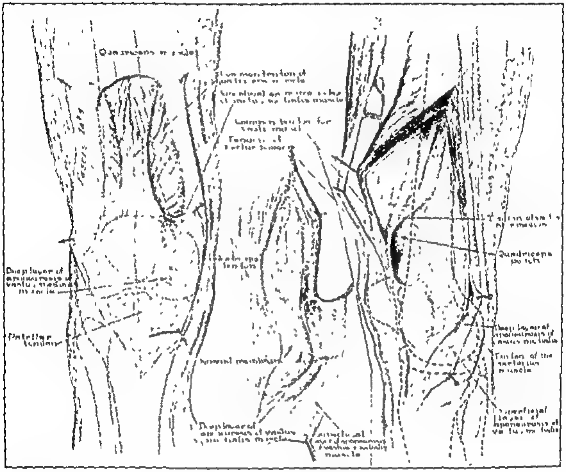


Fig 13-30 Anatomic dissections showing the three divisions of the quadriceps tendon, the synovial membrane, the quadriceps pouch and the aponeurotic insertions of the vasti muscles into the patella and tibia (From Abbott, L. C, and Carpenter, J. J. Bone & Joint Surg., 27:277, 1945 Courtesy Dr LeRoy C Abbott and associates)

and the upper border of the tibia. This layer fuses with the iliotibial band and the fascia enclosing the biceps muscle. The surgeon should note the various fascial layers which facilitate exposure of the joint and closure of the wound On the anteromedial surface, four layers of fascia are found, namely: the superficial fascia, often indistinct and of little importance; the fascia lata, sometimes blended with the anterior layer of the aponeurosis of the vastus medialis; and the deep layer of the aponeurosis of the vastus medialis. On the anterolateral aspect of the knee, the blending of the fibrous aponeurosis with the iliotibial tract is so intimate that only two layers are distinguishable, the superficial fascia and a layer of deep fascia and fibrous aponeurosis (Saunders).

The important landmarks are the quadriceps tendon, the patella, the patellar tendon, the condyles of the femur, and the tuberosities of the tibia. On the anteromedial aspect of the knee joint a triangular space is formed, the boundaries of which are the patellar tendon in front, the condyle of

the femur and the anterior margin of the tibial collateral ligament behind, and the upper margin of the tibia below. A similar space is formed on the anterolateral aspect of the knee joint, bounded in front by the patellar ligament, behind by the condyle of the femur and the fibular collateral ligament, and below by the margin of the tibia. With the knee in extension, the quadriceps tendon forms an obtuse angle with the patella and the patellar tendon of approximately 170 degrees (Callander). Curvilinear incisions are, therefore, preferable for those approaches in which either the patella or the aponeurotic expansions of the vasti are divided to enter the joint. With the knee in flexion, the iliotibial tract and the biceps tendon stand out prominently as they pass to their respective insertions into the lateral margin of the tibia and the head of the fibula. On the posteromedial surface of the joint the tendons of the sartorius, gracilis, and semitendinosus are seen where they insert into the medial aspect of the upper end of the tibia.

Synovia and Bursae. The synovial membrane lines the aponeurotic and the fibrous portions of the capsule. It extends upward beyond the articular surface of the distal end of the femur, on the anterior aspect of the joint, in the form of a cul-de-sac which lies under cover of the tendon of the quadriceps muscle. The upper part of this cul-de-sac usually communicates with the suprapatellar bursa. A pouchlike extension or diverticulum is prolonged posteriorly and distally on the tendon of the popliteus muscle. This diverticulum sometimes communicates with the capsule of the upper tibiofibular joint. A second pouch of synovial membrane often connects with a bursa which lies between the tendon of the semimembranosus and the tendon of origin of the inner head of the gastrocnemius. These pouches are important in sepsis of the knee joint. They may provide the pathways of extension of pus from the anterior compartment of the joint with the formation of a popliteal abscess (Fig. 13-31 A and B).

The semilunar cartilages (menisci) lie between the outermost portions of the articulating surfaces of the femur and the upper end of the tibia. They are wedge-shaped structures, free at their inner margins, but attached to the tibia at their outer surfaces by the coronary ligaments. Each cartilage presents two extremities or horns, which are fixed by fibrous attachments to the intercondylar eminence on the upper surface of the tibia.

Blood Supply. The blood supply to the knee joint and its surrounding structures is furnished by the genicular branches of the popliteal artery, the arteria genus suprema, a branch of the femoral artery, the descending branch of the lateral circumflex artery, and the recurrent branch of the anterior tibial artery (Fig. 13-31 D).

Cutaneous Nerves. An accurate anatomic knowledge of the cutaneous nerves is important to the surgeon because their injury may lead to disturbance of sensation or to the formation of painful neuromas. For example, division of the infrapatellar branch of the saphenous nerve at the time of an operation for removal of the internal semilunar cartilage (medial meniscus) may cause a painful neuroma with symptoms which are similar to those for which the cartilage was removed. The writers

have seen several such cases, in which removal of the neuromas gave complete relief of symptoms. These cutaneous nerves are of further significance, because the operating surgeon can use them as anatomic landmarks and guides to deeper structures. For example, the posterior cutaneous nerve of the calf can be identified as it lies between the heads of the gastrocnemius and traced to its origin from the posterior tibial nerve. A needless and often prolonged search in the popliteal fat for the sciatic nerve and its divisions and popliteal vessels is thus avoided.

SURGICAL APPROACHES TO THE KNEE JOINT

I. Approaches to the Anterior Aspect of the Knee Joint
  - A. The Parapatellar Incisions
    1. The median parapatellar incision (Langenbeck)
    2. The S-shaped parapatellar incision (Payr)
    3. The oblique parapatellar incision (Erkes)
    4. The lateral parapatella incision (Kocher)
  - B. Incisions Which Divide the Patella
    1. Vertical division of the patella (Brackett and Hall, Jones)
    2. Transverse division of the patella (von Volkmann)
    3. Sagittal division of the patella (Devine)
    4. Oblique division of the patella (Bougot and de la Rue)
  - C. Incisions Which Divide the Tendon of the Quadriceps Muscle
    1. Plastic division of the quadriceps tendon (Putti, Campbell)
    2. Plastic division of the quadriceps tendon (Coonse and Adams)
  - D. Incisions Which Divide the Tendon of the Patella Transversely
    1. The U-shaped incision (Textor)
    2. The H-shaped incision (Ollier)

II. Approaches to the Medial Aspect of the Knee Joint
  - A. The S-shaped Incision
  - B. The Straight or Curved Incision

III. Approaches to the Lateral Aspect of the Knee Joint
  - A. The S-shaped Incision
  - B. The Straight or Curved Incision

IV. Approaches for the Removal of the Semilunar Cartilages (The Menisci)
  - A. Partial Removal of the Internal Semilunar Cartilage
  - B. Complete Removal of the Internal Semilunar Cartilage
  - C. Partial Removal of the External Semilunar Cartilage
  - D. Complete Removal of the External Semilunar Cartilage

V. Bilateral Incisions
  - A. Exposure of the Popliteal Face of the Femur (Henry)
  - B. Approach for Epiphysiodesis (Abbott and Gill)
  - C. Removal of Loose Bodies from the Posterior Compartment of the Knee (Henderson)
  - D. Posterior Capsulotomy in Flexion Contractures of the Knee (Wilson)

VI. Approaches to the Posterior Aspect of the Knee
  - A. The Midline Approach Through the Popliteal Space

VII. Approaches for Drainage of Sepsis of the Knee Joint
  - A. Parapatellar Approaches
    1. Vertical (single, multiple, bilateral)
    2. Horizontal (bilateral)
  - B. The U-shaped Incision
  - C. Posteromedial, Tibial Incision (Abbott)
  - D. Posteromedial, Femoral Incision (Klein)
  - E. Incisions for Counterdrainage on the Posterolateral Aspect of the Knee

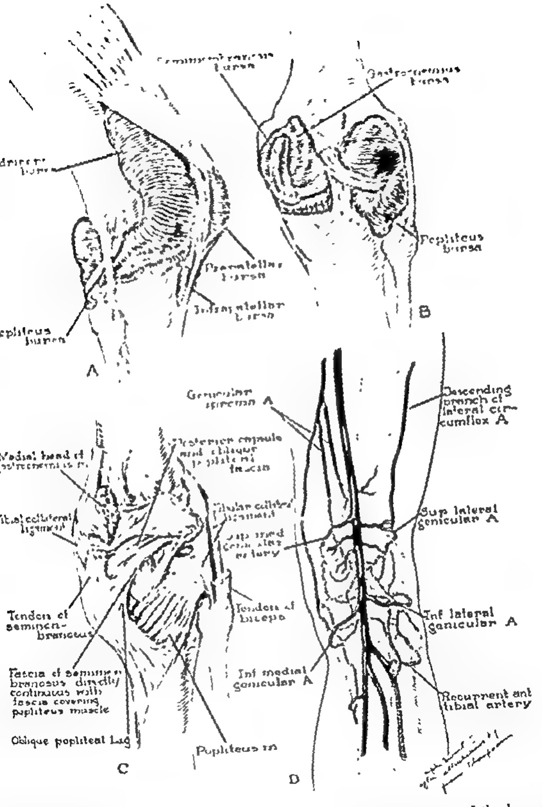


Fig 13-31 A, anterolateral aspect of the knee joint B, posterior aspect of the knee joint. C, muscles and ligaments in the popliteal space D, the collateral circulation about the knee. (From Abbott, L. C, and Carpenter, J J Bone & Joint Surg, 27 277, 1945. Courtesy Dr. LeRoy C Abbott and associates)

In the following paragraphs the commonly employed parapatellar approach for exploration of the knee, the incisions used for removal of the semilunar cartilages and repair of the collateral ligaments, and for drainage of pus in sepsis of the knee joint will be described. For description of other approaches, the reader is referred to the article entitled *Surgical Approaches to the Knee Joint,* by Abbott and Carpenter.

I. Approaches to the Anterior Aspect of the Knee Joint.

A. Parapatellar Incisions: the Median Parapatellar Incision (Langenbeck)

1. *Indications.* (a) Exploration of the joint, (b) synovectomy, (c) osteochondritis dissecans, (d) removal of loose bodies (joint mice), (e) repair of the cruciate ligaments, (f) removal of the infrapatellar fat pad.

2. *Position of the Patient.* The patient is supine with the knee on a sandbag and flexed from 20 to 30 degrees.

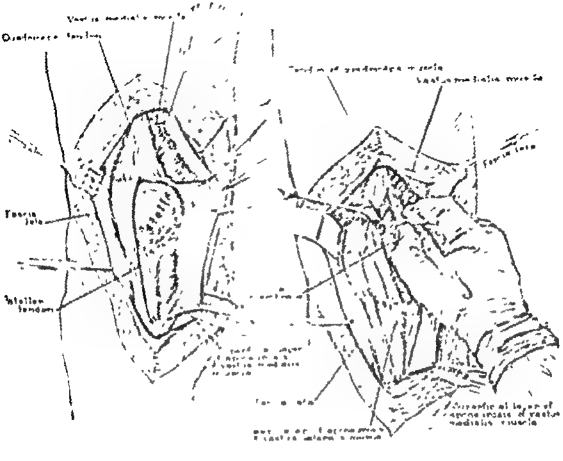
3. *Landmarks.* (a) Tibial tubercle, (b) patellar tendon, (c) patella, (d) quadriceps tendon, (e) vastus medialis, (f) adductor tubercle.

4 *Incision.* The incision is begun over the medial portion of the quadriceps tendon, 4 inches above the upper border of the patella. It is continued downward in a gentle curve following the medial margin of the quadriceps tendon, the medial border of the patella, and the patellar tendon. It next crosses the upper end of the tibia, and ends inferior to the tubercle of the tibia. One of two methods of exposure of the joint may be followed. In the first method, the deep fascia is incised and the quadriceps tendon is defined. This tendon is split in a vertical direction ⅓ of an inch lateral to its medial border. The incision is continued downward with division of the aponeurosis of the vastus medialis following the medial border of the patella and the patellar tendon. Just below the tubercle of the tibia, the periosteum is divided obliquely and reflected laterally for a short distance to free only the medial portion of the insertion of the patellar tendon. This procedure facilitates displacement of the patella (Fig. 18-32).

Greater access to the joint may be secured in four ways: 1, by division of the quadriceps tendon at a higher level; 2, by turning the upper end of the incision obliquely inward and separating the fibers of the vastus medialis, 3, by vertical section of the medial border of the alar ligament and adjacent fat pad, and 4, by freeing the patellar tendon subperiosteally on its medial aspect.

The structures which are exposed are:

1. Quadriceps pouch;
2. Condyles of the femur,
3. Posterior surface of the quadriceps tendon, and the posterior surfaces of the patella and the patellar tendon;
4. Infrapatellar fat pad,
5. Ligamentum mucosum,
6. Origin of the anterior cruciate ligament and the insertion of the posterior cruciate ligament,
7. Anterior margins of the upper end of the tibia and the semilunar cartilages.



A B

Fig 13-32 The medial parapatellar incision A, fascia lata and the superficial layer of the aponeurosis of the vastus medialis muscle B, division of the deep aponeurotic layer of the vastus medialis muscle (Courtesy Dr LeRoy C Abbott and associates)

The wound is closed with interrupted sutures to the deep layers of the fibrous aponeurosis and synovial membrane, to the fascia lata and the superficial layer of the fibrous aponeurosis directly over the center of the patella and to the skin

II and III. Approaches to the Medial and Lateral Aspects of the Knee Joint. The approaches to the medial and lateral aspects of the knee joint are used chiefly for exposure and repair of rupture of the tibial and fibular collateral ligaments.

A. The S-shaped Incision (Medial Aspect)

1. *Indications.* (a) Rupture of the tibial collateral ligament, especially when accompanied by injury to the anterior cruciate ligament and the internal semilunar cartilage (medial meniscus); (b) repair of neglected tears of the tibial collateral ligament, which requires the use of the medial hamstring tendons.

2. *Position of the Patient.* The knee is supported on a narrow sandbag well above the level of the opposite leg in a position of from 15 to 20 degrees of flexion and in slight external rotation.

3. *Landmarks.* (a) Adductor tubercle of the femur, (b) medial hamstring muscles, (c) condyle of the tibia, (d) joint line, (e) tibial tubercle.

4. *Incision.* A curvilinear incision of the skin and subcutaneous tis-

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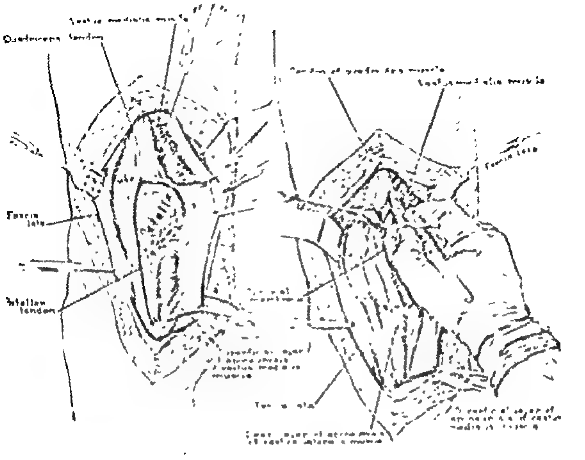
5. Ligamentum mucosum,
6. Origin of the anterior cruciate ligament and the insertion of the posterior cruciate ligament,
7. Anterior margins of the upper end of the tibia and the semilunar cartilages.



A B

Fig. 13-32. The medial parapatellar incision. A, fascia lata and the superficial layer of the aponeurosis of the vastus medialis muscle. B, division of the deep aponeurotic layer of the vastus medialis muscle. (Courtesy Dr. LeRoy C. Abbott and associates.)

The wound is closed with interrupted sutures to the deep layers of the fibrous aponeurosis and synovial membrane, to the fascia lata and the superficial layer of the fibrous aponeurosis directly over the center of the patella and to the skin.

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4. *Incision.* A curvilinear incision of the skin and subcutaneous tis-

sue is made, beginning 2 inches above the adductor tubercle on the posteromedial aspect of the joint, directly over the tendons of the sartorius and gracilis. It follows the course of these tendons to the level of the joint, where it is then curved gently forward along its margin to the anterior border of the upper end of the tibia. Here it is turned downward again to end just below the tibial tubercle. The skin and subcutaneous tissue are reflected upward and downward from the surface of the deep fascia. The deep fascia is then incised in a vertical direction from the adductor tubercle to the medial surface of the upper end of the tibia. The structures which are identified are the insertion of the adductor magnus into the adductor tubercle, and the long superficial segment of the tibial collateral ligament passing to the medial surface of the upper end of the tibia. The tendons of the sartorius, gracilis, and semitendinosus are reflected posteriorly to expose the oblique segments of the tibial collateral ligament and the tendinous insertion of the semimembranosus into the posterosuperior aspect of the upper end of the tibia. Posterior to the sartorius muscle, the saphenous nerve and the posterior division of the medial femoral cutaneous nerve are seen. Inferiorly, the infrapatellar branch of the saphenous nerve passes through the sartorius, and lies on the deep fascia ¼ of an inch below the medial margin of the tibia.

Anterior to the long superficial segment of the tibial collateral ligament, the aponeurosis and synovial membrane are incised to expose the anterior compartment of the joint. The anterior cruciate ligament and the anterior portion of the semilunar cartilage (medial meniscus) are then identified. An incision is made through the oblique segments of the tibial collateral ligament to expose the posterior extremity of the internal semilunar cartilage (medial meniscus). In late operations for repair of the tibial collateral ligament, particularly where its posterior oblique segments have been torn or where the tendons of the gracilis or semitendinosus are to be used to reinforce the inner aspect of the joint, the sartorius muscle is retracted anteriorly, instead of posteriorly. This makes it imperative to identify the saphenous nerve and its infrapatellar branch. Unless the dissection is carried deep to the fascia lata, it is best to expose the saphenous vein, which is generally accompanied by the anterior branch of the medial cutaneous nerve of the thigh.

Structures which are made accessible by this curved incision are all parts of the tibial collateral ligament, the medial hamstring muscles, including the sartorius and gracilis, the entire internal semilunar cartilage (medial meniscus), the anterior cruciate ligament, the infrapatellar fat pad, and the medial margin of the ligamentum mucosum.

The S-shaped Incision (Lateral Aspect).

1. *Indications.* (a) Derangement of the fibular collateral ligament, (b) fractures of the lower end of the femur, (c) cysts of the external semilunar cartilage in the knee joint (largely confined to the lateral meniscus).

2. *Position of the Patient.* The leg may be placed on a sandbag above the level of its fellow, or the knee may be flexed at right angles over the edge of the table with the calf supported so that the posterolateral aspect of the knee is free. The writers prefer the Trendelenburg position, since it helps maintain the position of the patient.

3. *Landmarks.* (a) Lateral condyle of the femur, (b) head of the fibula, (c) biceps tendon, (d) iliotibial band, (e) lateral aspect of the joint line, (f) patella, (g) infrapatellar tendon.

4. *Incision.* The incision is similar to the incision for complete exposure of the medial aspect of the joint. It is begun about 2 inches above the lateral condyle of the femur, lying well posteriorly in the sulcus between the tendon of the biceps muscle and the iliotibial tract. It is continued directly forward, following the lateral margin of the upper end of the tibia, and is then curved downward to the tibial tubercle. The structures exposed are the biceps tendon, the posterolateral part of the joint capsule, the fibular collateral ligament and the lower part of the iliotibial tract. The peroneal nerve is found lying just behind the biceps tendon. From here it can be traced to the lateral aspect of the neck of the fibula. The biceps tendon is followed to its insertion into the fibula, where it will be found to bifurcate in order to enclose the fibular collateral ligament. At this stage, the ligament is followed upward to its attachment into the epicondyle of the femur. Lying deep and slightly posterior to the fibular collateral ligament, the tendon of the popliteus is exposed. If the anterior aspect of the joint is to be entered, the anterior portion of the fibrous aponeurosis of the vastus lateralis and the synovial membrane are excised in a direction downward and forward. The anterior half of the external semilunar cartilage (lateral meniscus) is readily exposed without division of the tendinous fibers of the iliotibial tract. By this incision an excellent approach is obtained to the fibular collateral ligament, the biceps tendon, the common peroneal nerve, the posterior joint line, the iliotibial tract, the entire semilunar cartilage (lateral meniscus), the lateral aspect of the fat pad, and the infrapatellar tendon.

B. The Straight or Curved Incision. Space does not permit discussion.

IV. Approaches for the Removal of the Semilunar Cartilages (the Menisci).

A. For Partial Removal of the Internal Semilunar Cartilage (Medial Meniscus).

1. *Position of the Patient.* The patient is in a slightly Trendelenburg position, with the knee flexed to 90 degrees over the end of the table.

2. *Landmarks.* (a) Medial condyle of the femur, (b) tibial tubercle, (c) patellar tendon, (d) patella, (e) anteromedial joint line.

3. *Incision.* The incisions which may be used for partial removal of the internal semilunar cartilage are the curved incision with an anterior convexity (Jones), the curved incision with a posterior convexity (Fisher), the oblique or nearly transverse incision, and the vertical incision (Fig. 13-33). These incisions are made in order to expose the joint adequately, and they vary in their directions according to the decision of the surgeon. The structures which are exposed are the infrapatellar fat pad, the ligamentum mucosum, the anterior portion of the origin of the anterior cruciate ligament, and the anterior two thirds of the semilunar cartilage (medial meniscus).

The curved skin incision, with an anterior convexity, is made on the anterior surface of the medial condyle of the femur, on a level with the lower portion of the patella. It is curved gently downward to the level of

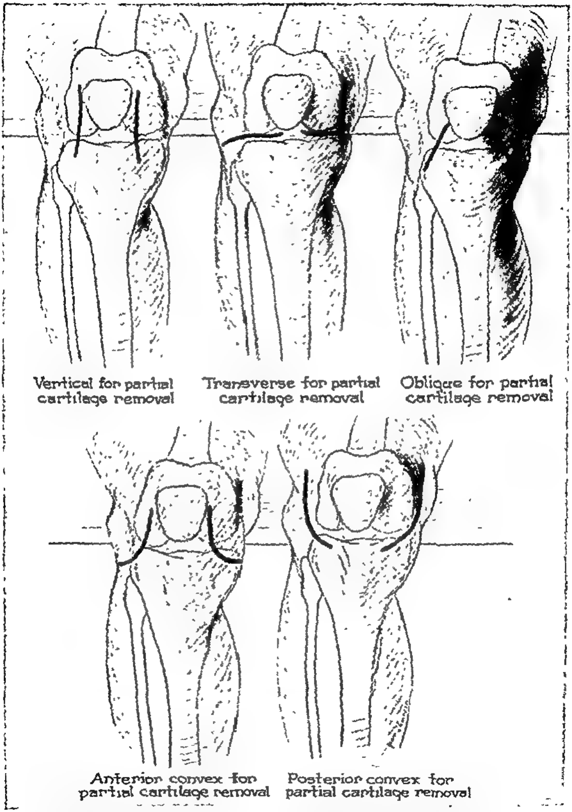

Fig. 13-33 Incisions used for partial removal of the semilunar cartilages (From Abbott, L. C, and Carpenter, J. J Bone & Joint Surg, 27 277, 1945 Courtesy Dr. LeRoy C Abbott and associates.)

the tibia, and backward along its upper margin for a distance of ¾ of an inch. In the subcutaneous tissue, the infrapatellar branch of the saphenous nerve is identified ½ an inch below the medial margin of the tibia. It is freed and retracted, with exposure of the aponeurosis of the vastus medialis. This aponeurosis and synovial membrane are incised, and the joint is entered.

B. For Complete Removal of the Internal Semilunar Cartilage (Medial Meniscus).

1. *Indications.* (a) Derangements of the cartilage, especially when the posterior portion is damaged. (b) cysts of the semilunar cartilage, (c) exposure of the anterior portion of the tibial collateral ligament.

2. *Position of the Patient* The patient is supine in a partial Trendelenburg position, with the knee flexed 90 degrees over the end of the table. The calf of the leg is supported from behind, to free completely the posteromedial aspect of the knee

3. *Landmarks.* (a) Medial condyle of the femur, (b) medial tibial tubercle, (c) patellar tendon, (d) patella, (e) anteromedial joint line.

4. *The Cave Incision* The skin incision is begun ¾ of an inch above and behind the internal femoral epicondyle. It is then curved downward to the joint line, and then forward ¼ of an inch below the joint line to the patellar tendon. The flap formed of skin and subcutaneous tissue is dissected upward to expose the vastus aponeurotic expansion and the tibial collateral ligament. The anterior part of the joint capsule is incised just in front of the tibial collateral ligament, and the synovia is opened through the same incision. The posterior capsule of the joint is then opened behind the long superficial segment of the tibial collateral ligament. Therefore, two openings are made into the joint—one in front of, and one behind the tibial collateral ligament. The accessible structures are the internal semilunar cartilage (medial meniscus) and the medial part of the fat pad (Fig. 13-31).

Closure is effected by interrupted sutures to the fibrous aponeurosis and the fibrous capsule lying respectively in front of and behind the tibial collateral ligament.

5. *The Incision of Bosworth.* An oblique incision, slanting upward and slightly backward, is made over the anteromedial aspect of the joint. The skin and subcutaneous tissues are reflected forward, and the capsule is opened by a vertical incision at the usual point anteriorly, in line with its fibers. The synovial membrane above the meniscus is opened between two pairs of forceps, care being taken not to cut the articular surface of the underlying femoral condyle. The small synovial pouch below the meniscus should be opened in a similar fashion. By means of curved scissors, one blade of which is placed above and the other below the meniscus, the anterior end of the meniscus can be freed from the synovial membrane and the coronary ligaments. The knee is then flexed, and the skin and subcutaneous tissue are dissected backward to the collateral ligament, close to the capsule of the joint This capsule is opened along the posterolateral margin of the femoral condyle behind the collateral ligament by a vertical incision in line with its fibers. The anterior portion of the meniscus is then passed backward under the collateral ligament, and its posterior third can

be visualized extending into the back of the joint. The posterior third is freed as far as the posterior tibial spine. When the knee is straightened, the posterior incision will be found to close tightly. The anterior incision of the capsule is closed with a few interrupted sutures.

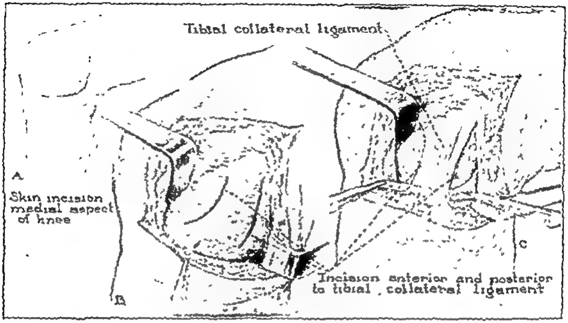

Fig 13-34 The Cave incision for removal of the internal semilunar cartilage. (*From* Abbott, L. C., and Carpenter, J. J. Bone & Joint Surg, 27:277, 1945. Courtesy Dr. LeRoy C. Abbott and associates)

In this approach the surgeon flexes and then extends the knee to facilitate exposure of the anteromedial and posteromedial portions of the joint.

C and D. Removal of External Semilunar Cartilage. Space does not permit discussion.

V. Bilateral Incisions. Space does not permit description of this approach.

VI. Approaches to the Posterior Aspect of the Knee. Space does not permit description of these approaches.

VII. Approaches for Drainage of Sepsis of the Knee Joint. The incisions used in sepsis of the knee joint are devised to drain the anterior compartment of the knee and the popliteal space. The structures which separate the anterior compartment and the popliteal space are the lateral and medial intermuscular septa, the fibular collateral ligament, and the tibial collateral ligament. If incisions are made to expose the anterior surfaces of the intermuscular septa, the anterior compartment of the joint is exposed. If the posterior surfaces of the septa are followed, the popliteal space is entered. In the popliteal space, there are certain fascial planes and bursae which are worthy of consideration. The bursae between the semimembranosus and the medial head of the gastrocnemius frequently communicate with the knee joint. Consequently, incisions opening these bursae often lead directly into the joint. This is the rationale of the Klein approach on the posteromedial aspect of the joint. The popliteus tendon pierces the capsule of the joint, and a pouch of synovial membrane is prolonged on the anterior surface of the popliteus muscle. This latter is the rationale for the posteromedial incision

for drainage of a popliteal abscess (Fig 13-31 B and C). The fascia of the semimembranosus and the popliteal fascia form a continuous sheath overlying the posterior compartment of the joint. Incisions from the posteromedial surface of the tibia can be followed along the anterior surface of the popliteus muscle to the postero-external aspect of the knee. Furthermore, this incision can be carried to the posteromedial condyle of the femur by dividing the insertion of the semimembranosus to the posterior part of the tibia. This permits adequate drainage of the posterior aspect of the knee, without exposing the popliteal vessels to the irritation of pus and drains which can often lead to serious secondary hemorrhage, and not infrequently to amputation.

A. Parapatellar Incisions

1. *Indications* Drainage of the anterior compartment of the knee joint.

2. *Position of the Patient* The patient is supine with the knee in slight flexion.

3. *Landmarks.* (a) Patella, (b) joint line, (c) condyles of the femur, (d) head of the fibula.

4. *Incision.* Two vertical parapatellar incisions are made on both sides of the knee. They extend from the apex of the patellar pouch above to the margin of the tibia below. Alternative vertical incisions are of the multiple short variety, or two horizontal incisions may be made extending backward from the middle of the patella to the anterior margins of the collateral ligaments. In these incisions, it is often necessary to sew synovial membrane to the skin to ensure adequate drainage, as no drains are placed within the joint.

B. The U-shaped Incision. Space does not permit discussion.

C. The Posteromedial, Tibial Incision (Abbott).

1. *Indications.* Drainage of popliteal abscess.

2. *Position of the Patient.* The patient is supine, with the knee flexed to 30 degrees, and the hip in external rotation. The side of the foot rests on the opposite tibia. The prone position may also be used with the entire lower extremity on a sandbag well above the level of its fellow.

3. *Landmarks.* (a) Posteromedial border of the tibia, (b) posteromedial border of the medial and lateral condyles of the femur, (c) internal hamstring group.

4. *Incision.* An incision, 4 inches in length, is made through skin and subcutaneous tissue over and well behind the posteromedial border of the upper one fourth of the tibia to avoid exposure of the saphenous vein and nerve. These structures lie anteriorly in the subcutaneous fat, the vein usually in two divisions, one placed subcutaneously, and the other lying in the subfascial portion. The deep fascia is incised in line of the skin incision, and the soft parts are drawn forward to expose the posteromedial border of the tibia.

The posteromedial border of the tibia and the fascial (Fig. 13-35A) covering of the medial head of the gastrocnemius are now exposed. This fascia is incised, and the gastrocnemius muscle is traced upward as far as its tendinous insertion of origin from the femur. The muscle is separated from its fascial covering to permit its retraction inward. The posterior surface of the upper end of the tibia is now displayed. Upon it lies the popliteus muscle

and its insertion into the medial side of the tibia at the oblique line. From the oblique line, passing downward and medially, the fibrous origin of the soleus from the tibia is seen. The popliteus muscle is covered by fascia which is directly continuous with the fascia overlying the semimembranosus.

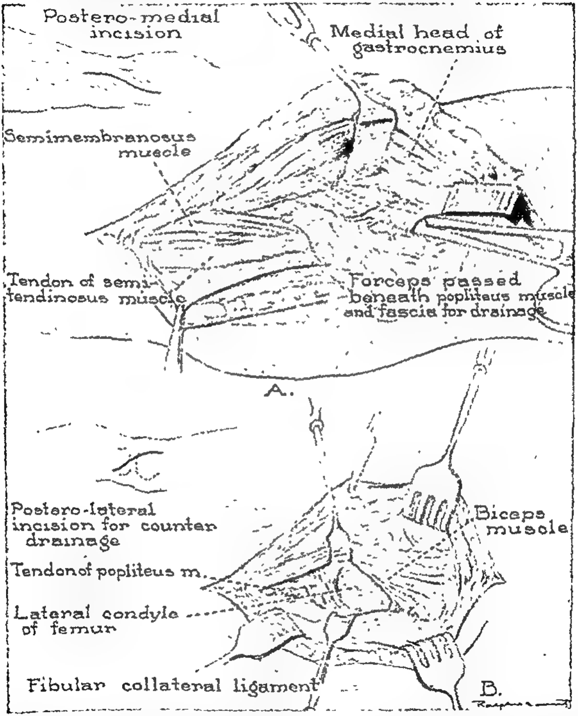

Fig. 13-35. A, the incision on the posteromedial aspect of the upper end of the tibia for drainage of popliteal abscess. B, the posterolateral incision for counter drainage of popliteal abscess. (From Abbott, L. C., and Carpenter J. J. Bone & Joint Surg., 27:277, 1945. Courtesy Dr. LeRoy C. Abbott and associates.)

At the upper border of the popliteus, the inferomedial genicular vessels are disclosed; while lateral and posterior to the popliteus, the posterior tibial nerve and artery can be felt as they are crossed by the tendon of the plantaris. The insertion of the popliteus into the tibia is divided, and the clamp passed

upward and outward along its anterior surface until it reaches the external condyle of the femur. This pad of muscle and popliteal fascia forms a protection for the popliteal vessels, veins, and nerves which lie posteriorly.

D. POSTEROMEDIAL FEMORAL INCISION. Space does not permit discussion.

E. INCISIONS FOR COUNTERDRAINAGE ON THE POSTEROLATERAL ASPECT OF THE KNEE. Curved or straight incisions for drainage on the posterolateral surface of the knee are made between the iliotibial tract and the biceps tendon. The capsule is incised behind the fibular collateral ligament, with exposure of the tendon of the popliteus muscle where it inserts into the lateral epicondyle of the femur. If used with the posteromedial approach, through-and-through drainage is obtained (Fig. 13-35B).

JOINTS OF THE ANKLE AND FOOT

General Anatomic Considerations. The ankle joint, a ginglymus or hinge joint, is formed by the articulation of the lower tibia and fibula with the superior surface of the body of the talus. The capsule enclosing the joint is attached to all bony prominences and supporting ligaments. Anteriorly, the capsule is thin and membranous, posteriorly, it is relaxed.

The articulation between the calcaneus and talus, or the so-called subastragalar joint, is divided into anterior and posterior parts. The anterior part is formed by the articulation of the round head of the talus with the navicular in front and the facet on the sustentaculum tali below, the posterior part is formed by articulation of the large facet on the posterosuperior surface of the calcaneus with the inferior surface of the body of the talus. The two parts of the joint are separated by a space termed the sinus tarsi, the roof of which is formed by the under surface of the neck of the talus and the margins of the cruciate ligaments while its floor is formed by a nonarticulating portion of the superior surface of the body of the calcaneus. This space is filled by fat and several ligaments, the most important being the strong interosseous ligament which unites the talus and the calcaneus.

The so-called transverse or midtarsal joint is in reality made up of two distinct joints with individual joint capsules and synovial membranes, the talonavicular and the calcaneocuboid joints. Their joint surfaces lie approximately on a horizontal line across the center of the foot (Fig. 13-36).

The naviculocuneiform joint is a common joint space for the articulation of the navicular with the three cuneiform bones. The cuneiform bones in turn articulate anteriorly with the three inner metatarsal bones, though at different levels across the tarsus. A recess is formed between the distal halves of the first and second cuneiform bones into which the base of the second metatarsal is mortised. The fourth and fifth metatarsals articulate with the cuboid. The distal tibiofibular syndesmosis is formed by the notched lower end of the tibia and the roughly triangular surface of the lower end of the fibula. They are bound together by an interosseous ligament reinforced by anterior and posterior tibiofibular ligaments.

The principal motions at the ankle joint are flexion and extension; at the subastragalar joint, inversion and eversion; and at the midtarsal joint, abduction and adduction. These motions at the three joints give

to the ankle and foot its remarkable flexibility and resiliency. Loss of motion in one of these joints through injury or disease is often compensated for by an increased range of motion in the joints which are still functioning. For example, fusion of the ankle is generally followed by an increased range of motion in the midtarsal joint. Furthermore, the surgeon should regard these three joints as a functioning unit, particularly in planning his treatment of those paralytic conditions which require tendon transplantation for reestablishment of balance or arthrodesis for creation of stability.

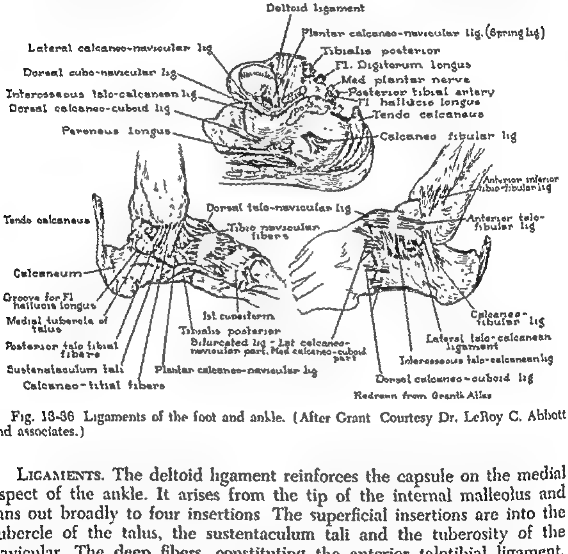

Fig. 13-36 Ligaments of the foot and ankle. (After Grant Courtesy Dr. LeRoy C. Abbott and associates.)

Ligaments. The deltoid ligament reinforces the capsule on the medial aspect of the ankle. It arises from the tip of the internal malleolus and fans out broadly to four insertions The superficial insertions are into the tubercle of the talus, the sustentaculum tali and the tuberosity of the navicular The deep fibers, constituting the anterior talotibial ligament, pass transversely from the nonarticulating portion of the lateral surface of the internal malleolus to insert into the medial surface of the body of the talus, binding firmly together these parts of the bones (Fig. 13-36). Therefore, in fractures of the internal malleolus with lateral displacement of the talus in which the deep transverse portion of the deltoid ligament has been uninjured, reduction of the fracture dislocation, once accomplished, can be maintained by internal fixation of the fracture of the internal malleolus.

On the lateral aspect of the ankle joint there are six ligaments which concern the surgeon. Three unite the fibula and tibia at the distal tibiofibular syndesmosis. The interosseous ligament is a continuation of the interosseous membrane and binds the tibia and fibula closely together at their triangular

areas just proximal to the ankle joint. The anterior and posterior inferior tibiofibular ligaments are stout bands stretching from the tibia to the fibula at the level of the ankle joint. Binding the fibula to the talus are the anterior and posterior talofibular ligaments. The anterior ligament is the smaller of the two and passes from the anterior border of the lateral malleolus to the neck of the talus. The posterior ligament passes medially from the fossa on the tip of the malleolus to the posterior tubercle of the talus. The fibula is bound to the calcaneum by the cord-like calcaneofibular ligament. These ligaments add strength to the lateral aspect of the ankle and subastragalar joints. They must be severed to gain access to the distal tibiofibular and talofibular articulations.

The fascial structures at the ankle joint which are of surgical importance are the extensor retinaculum, the superior and inferior peroneal retinacular and the laciniate ligament. The extensor retinaculum has an upper and a lower part termed respectively the transverse crural and cruciate crural ligaments. The transverse crural ligament binds down the extensor tendons on the front of the foot and keeps them from bowstringing as they cross the front of the ankle joint. The cruciate crural ligament, serving the same function, is a Y-shaped band, the stem of which arises from the anterolateral surface of the calcaneus. The two arms of the band pass medially, the upper one inserting into the medial malleolus and the lower one into the fascia over the first cuneiform bone. The peroneal retinaculum likewise has two parts which tie the peroneus brevis and peroneus longus tendons to the lateral surface of the calcaneus as they pass around the lateral side of the ankle joint. The laciniate ligament extends downward from the internal malleolus to the medial surface of the calcaneus to form four tunnels which house the tendons of the tibialis posticus, the flexor digitorum longus and the flexor hallucis longus muscles, and the neurovascular bundle in separate compartments. The tendons lie in the order named from before backward. The neurovascular bundle, containing the posterior tibial artery, its accompanying veins and the posterior tibial nerve, lies between the tendons of the flexor digitorum longus and the flexor hallucis longus. The artery is anterior to the nerve.

The sustentaculum tali lies in the course of these three tendons as they pass behind the medial malleolus, the tendons of the tibialis posticus and flexor digitorum longus muscles being anterior to, and the tendon of the flexor hallucis longus muscle lying posterior to, this bony prominence. The tendons of these three muscles pass across the longitudinal arch of the foot to their insertions into the cuneiforms and the terminal phalanges of the great and the other four toes.

Behind the external malleolus, the peroneus brevis and longus tendons pass across the lateral surface of the body of the calcaneus. The brevis inserts into the base of the fifth metatarsal bone, while the longus curves over the lateral surface of the cuboid and grooves the bone as it turns obliquely across the sole to insert into the inferior surfaces of the first cuneiform and base of the first metatarsal.

The tendons of four muscles which cross the front of the ankle joint from within outward are those of the tibialis anticus, the extensor hallucis and extensor digitorum longus, and the peroneus tertius. These tendons

to the ankle and foot its remarkable flexibility and resiliency. Loss of motion in one of these joints through injury or disease is often compensated for by an increased range of motion in the joints which are still functioning. For example, fusion of the ankle is generally followed by an increased range of motion in the midtarsal joint. Furthermore, the surgeon should regard these three joints as a functioning unit, particularly in planning his treatment of those paralytic conditions which require tendon transplantation for reestablishment of balance or arthrodesis for creation of stability.

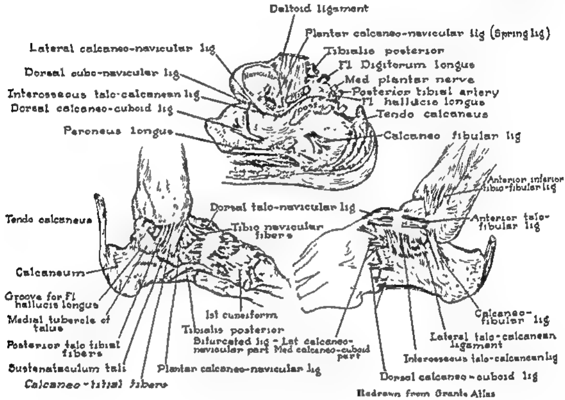

Fig 13-36 Ligaments of the foot and ankle. (After Grant. Courtesy Dr. LeRoy C. Abbott and associates.)

Ligaments. The deltoid ligament reinforces the capsule on the medial aspect of the ankle. It arises from the tip of the internal malleolus and fans out broadly to four insertions. The superficial insertions are into the tubercle of the talus, the sustentaculum tali and the tuberosity of the navicular. The deep fibers, constituting the anterior talotibial ligament, pass transversely from the nonarticulating portion of the lateral surface of the internal malleolus to insert into the medial surface of the body of the talus, binding firmly together these parts of the bones (Fig. 13-36). Therefore, in fractures of the internal malleolus with lateral displacement of the talus in which the deep transverse portion of the deltoid ligament has been uninjured, reduction of the fracture dislocation, once accomplished, can be maintained by internal fixation of the fracture of the internal malleolus.

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insert, respectively, into the medial cuneiform and first metatarsal, the base of the distal phalanx of the great toe, the bases of the distal phalanges of the four outer toes, and the base of the fifth metatarsal. At the level of the ankle the neurovascular bundle, made up of the anterior tibial artery and the deep peroneal nerve, lies between the tendon of the extensor hallucis longus and the tendons of the extensor digitorum communis muscles. The tendon of the extensor hallucis longus crosses the anterior tibial artery from without inward above the ankle joint, and lies medial to the dorsalis pedis artery on the dorsum of the foot. Beneath the tendons of the extensor digitorum longus muscle lies the fleshy belly and origin of the extensor digitorum brevis muscle. It arises from the anterolateral surface of the calcaneus and from the adjacent ligaments and fascia. Its four tendons insert into the proximal phalanges of the four medial toes.

Blood Vessels. The principal veins of the foot are the great and small saphenous veins. The great saphenous vein receives tributaries from the dorsal venous arch and from the sole of the foot through the medial marginal vein of the dorsum, then ascends in front of the medial malleolus. The small saphenous vein passes behind the lateral malleolus as a continuation of the lateral marginal vein of the foot.

The important arteries are the anterior, the posterior tibial and the peroneal arteries. A line from the medial aspect of the neck of the fibula to the interval between the first and second metatarsals denotes the course of the anterior tibial artery. At the ankle, the artery lies midway between the malleoli, between the tendons of the extensor hallucis longus and the extensor digitorum longus, where it becomes the dorsalis pedis. In the leg the artery is accompanied on its medial aspect by the deep peroneal, a branch of the common peroneal nerve, but at the ankle the nerve comes to lie on its lateral surface. There are two branches of the artery at the ankle, the medial anterior malleolar artery which arises about 5 cm. above the joint, and the lateral anterior malleolar artery which arises a little more distally. The former runs over the internal malleolus while the latter passes under the tendons of the extensor digitorum longus muscle. The anterior tibial artery becomes the dorsalis pedis below the level of the ankle and this vessel lies successively on the astragalus, navicular and second cuneiform bones before terminating in the first intermetatarsal space as the deep plantar and first dorsal metatarsal arteries. The lateral tarsal artery branches laterally from the dorsalis pedis to cross the navicular, while the arcuate artery takes off more distally at the bases of the metatarsal bones. The metatarsal arteries stem from the arcuate.

From its position behind the medial malleolus, the posterior tibial artery passes under cover of the abductor hallucis muscle and divides into the medial and lateral plantar arteries which supply the sole of the foot. The tibial nerve divides in a similar manner into the medial and lateral plantar nerves which accompany the plantar arteries in the sole of the foot.

The peroneal artery, a branch of the posterior tibial, lies in a fibrous canal deep on the posterolateral side of the leg between the tibialis posticus and flexor hallucis longus muscles. Just above the level of the ankle it gives off a perforating branch which passes through the interosse-

ous membrane and over the tibiofibular syndesmosis to anastomose about the front of the ankle. The artery terminates in the lateral calcaneal branches which supply the heel and join the anastomosis around the ankle.

NERVES. The single motor nerve on the dorsum of the foot is the branch of the deep peroneal to the extensor brevis. All the intrinsic muscles on the plantar surface of the foot are supplied by the tibial nerve through either the medial or lateral plantar nerve.

Several cutaneous nerves are important to the surgeon and should be preserved when possible. The superficial *peroneal nerve* pierces the deep fascia at the lower third of the leg and divides into the medial dorsal and intermediate dorsal cutaneous branches. They *provide sensation to the dorsal and lateral surfaces of all of the toes except for the web and* adjacent sides of the first and second toes. These areas are supplied by the terminal branch of the deep peroneal nerve which comes forward from under the extensor brevis muscle.

The sural nerve extends along the lateral border of the tendo Achilles, giving branches to the lateral aspect of the lower leg and heel. It passes beneath the lateral malleolus to continue forward as the lateral dorsal cutaneous nerve which provides sensation to the outer border of the foot and the small toe. The medial side of the foot is supplied by terminal branches of the saphenous nerve which accompanies the saphenous vein anterior to the medial malleolus.

SURGICAL APPROACHES TO THE JOINTS OF THE ANKLE AND FOOT

I. Approaches to the Ankle Joint
  - A. Anterolateral Approach
  - B. Lateral Approach (Saunders)
  - C. Posterolateral Approach (Kocher)
  - D. Medial Approach (Abbott)

II. Approaches to the Joints of the Foot
  - A. Approaches to the Tarsus
    1. Dorsolateral approach (Hoke)
    2. Lateral malleolar approach (Whitman)
    3. Dorsal approach (Abbott)
    4. Medial approach to the astragalonavicular and naviculocuneiform joints
  - B. Approaches to the Metatarsus and Phalanges
    1. Dorsal approach to the metatarsophalangeal joints
    2. Dorsal approach to the interphalangeal joints

I. Approaches to the Ankle Joint.

A. ANTEROLATERAL APPROACH.

Note. This is a most useful approach which provides good access with minimum damage to important structures.

1. *Indications* (a) Arthrotomy, (b) removal of loose bodies, (c) fractures involving the ankle, (d) excision of the joint, (e) arthrodesis.

2. *Position of the Patient.* The patient is supine on the table with the leg and foot elevated above its fellow by a sandbag.

3. *Landmarks.* (a) Lateral surface of the tibia, (b) anterior border of the fibula, (c) fibular malleolus, (d) interval between the tendons of the extensor digitorum longus muscle and the fibula.

4. *Incision.* The incision is begun on the anterolateral surface of the leg 2 or 3 inches above the level of the ankle joint and is carried downward

over the interval between the anterior margin of the fibula and the lateral border of the tendons of the extensor digitorum longus muscle. It is slightly curved with its convexity facing in a lateral direction and it is terminated on the dorsolateral surface of the foot over the bases of the fourth and fifth metatarsal bones (Fig. 13-37).

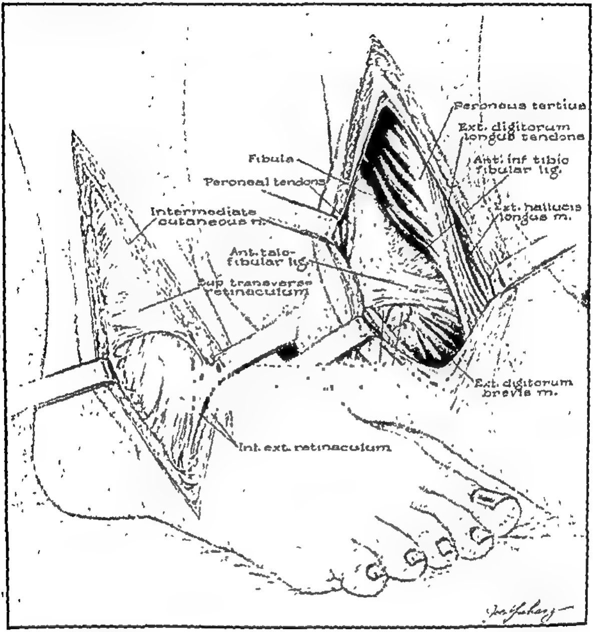

Fig. 13-37 Anterolateral approach A, incision exposing superior and inferior retinacula. B, the incision is carried down directly onto the fibula (Courtesy Dr LeRoy C Abbott and associates)

Without dissecting the skin from the underlying subcutaneous tissue and fascia and thus jeopardizing its blood supply, the incision is carried directly down to the periosteum of the fibula by incising the fascia and the cruciate crural ligaments longitudinally. The anterolateral malleolar and lateral tarsal arteries are clamped, cut and ligated. The intermediate dorsal cutaneous branches of the superficial peroneal nerve are identified and protected during retraction of the structures at the margins of the wound (Fig. 13-37B). On the dorsum of the foot, the origin of the extensor

digitorum brevis from the anterosuperior surface of the calcaneus is elevated with a sharp periosteal elevator and reflected distally.

When the extensor tendons are retracted medially, the capsule of the ankle joint is exposed and this is incised to reveal the ankle joint. By carrying the incision more distally toward the base of the fourth metatarsal, the talonavicular and calcaneocuboid joints can be exposed. Campbell has called this the "*universal incision*" for the foot and ankle, observing that the only joints of the tarsus which cannot be reached through it are those between the navicular and the first two cuneiform bones.

When the anterolateral approach is employed for arthrodesis of the ankle joint, the inferior tibiofibular syndesmosis is opened by severing the interosseous membrane, the anterior-inferior tibiofibular ligament, and the anterior talofibular ligament (Fig. 13-38 A and B). The capsule of the ankle joint is incised. The tibia and fibula are separated by a spreader to expose the posterior-inferior tibiofibular and posterior talofibular ligaments (Fig. 13-38 C). When these ligaments are severed the tibiofibular syndesmosis can be excised readily and the ankle joint denuded of articular cartilage (Fig. 13-39 A). This permits the fibula to collapse tightly against the tibia and talus thereby affording excellent contact of raw cancellous bone surfaces (Fig. 13-39 B).

Closure of the skin flap is all that is necessary as the extensor tendons fall into place.

B. Lateral Approach (Saunders).

1. *Indication.* Arthrodesis.

2. *Position of the Patient.* The patient lies on the unaffected side. On the side to be operated upon the knee is slightly flexed and the foot is supported on a sandbag with its lateral surface presenting.

3. *Landmarks.* (a) Lateral malleolus, (b) posterior border of the fibula, (c) base of the fifth metatarsal.

4. *Incision.* The incision is begun on the posterior margin of the fibula, 4 inches above its lower end. It is extended downward and around the external malleolus and then curved forward for about 2 inches toward Lisfranc's tubercle on the fifth metatarsal. The incision is deepened to the shaft of the fibula with no undermining of the skin edges. The periosteum of the fibula is incised with a sharp knife down to the origin of the collateral ligaments of the ankle joint at the tip of the malleolus. The fibula is then exposed subperiosteally throughout its lower third, and osteotomized well above the ankle joint on a sharply oblique angle so that the line of osteotomy is from 2 to 3 inches long. The lower fragment of the fibula is then swung outward and downward through an arc of 180 degrees into the lower angle of the wound, remaining attached only by the talofibular ligaments. This exposes the lateral aspect of the lower tibia, the ankle joint, and the astragalus.

The periosteum on the lateral surface of the tibia is then incised longitudinally and reflected anteriorly and posteriorly. The ankle capsule is then opened, and with a curved scissors the transverse fibers of the deltoid ligament on the medial side of the joint are divided. The foot is then inverted sufficiently to permit complete exposure of the cartilaginous surfaces of the lower end of the tibia, the internal malleolus and the talus.

This complete inversion may require tenotomy of the peroneal tendons. Removal of the cartilage for arthrodesis may then be carried out. The body of the astragalus is countersunk into the inferior surface of the tibia.

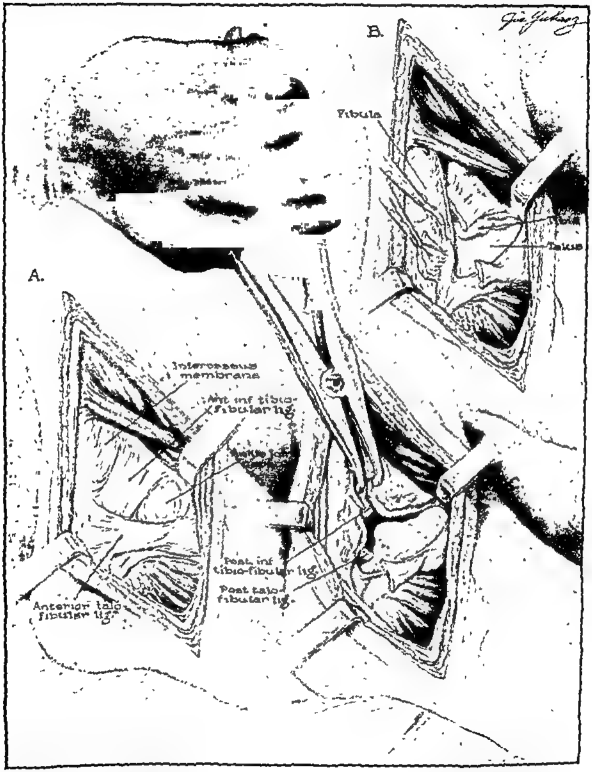

Fig. 13-38. A, exposure of anterolateral ligaments of ankle joint. B, ligaments and joint capsule severed. C, tibia and fibula separated to expose posterolateral ligaments of ankle joint. (Courtesy Dr. LeRoy C. Abbott and associates.)

In closure, a groove is made with a gouge on the lateral surface of the tibia and the distal fragment of the fibula is mortised into this groove. The proximal end of the fibula then overlaps the mortise and holds the

distal fragment of the fibula in place, making metal fixation unnecessary.

C. POSTEROLATERAL APPROACH. This approach, devised by Kocher, is useful for drainage of the ankle joint. It is similar to the Whitman approach for astragalectomy which will be described under approaches to the tarsus.

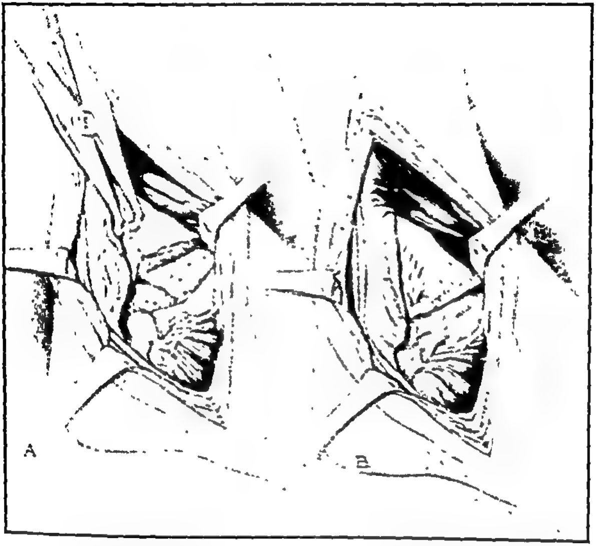

Fig. 13-39. A, articular cartilage removed from fibula, tibia and talus. B, fibula collapses tightly against tibia and talus following excision of inferior tibiofibular syndesmosis. (Courtesy Dr. LeRoy C. Abbott and associates.)

D. MEDIAL APPROACH (ABBOTT).

1. *Indications.* (a) Fractures of the internal malleolus, (b) arthrodesis of the ankle.

2. *Position of the Patient.* The patient is on the affected side with the knee slightly flexed and the foot supported by a sandbag with its medial aspect presenting.

3. *Landmarks.* (a) Medial malleolus, (b) neck of the astragalus, (c) posterior tibial tendon.

4. *Incision.* The incision of the skin is begun 2 inches above the ankle joint along the posterior border of the tibia and is curved distally around the tip of the medial malleolus to end over the tubercle of the

navicular. The precise level of the ankle joint is found by incising the deep fascia over the anteromedial surface of the internal malleolus and placing the end of a hemostat into the joint cavity where the malleolus joins the inferior surface of the tibia. The malleolus is then divided horizontally on a level with the cartilaginous surface of the tibia. Taking care to preserve both the superficial and deep transverse fibers of the deltoid ligament, the malleolus is rolled outward and downward. The foot is then everted and the joint cavity is exposed. To secure adequate exposure, however, it is sometimes necessary to tenotomize the tendon of the tibialis posticus muscle and elevate the periosteum on the anterior and posterior surfaces of the lower end of the tibia.

In fusion of the ankle, the cartilage is removed from the cartilaginous surfaces of the tibia, the astragalus, the internal malleolus, and the fibula. To obtain accurate approximation of the cancellous bone surfaces, it may be necessary to resect a segment of the fibula through a short vertical incision over the lateral aspect of its lower end. The authors have found, however, that with good exposure and careful freeing of the external malleolus through the medial incision, approximation of the joint surfaces can generally be secured without osteotomy of the fibula.

When closing, the medial malleolus is returned to its position and fixed with metal or sutures. The preservation of the deep transverse fibers of the deltoid holds the astragalus to the malleolus and helps to stabilize the ankle joint.

II. Approaches to the Joints of the Foot. The subastragalar and midtarsal joints may be exposed by either straight or curved incisions over the dorsolateral surfaces of the ankle and foot, these incisions being centered over the region of the sinus tarsi. Some surgeons prefer an incision which is made to curve around the external malleolus and is similar to those incisions employed by Kocher in his posterolateral approach to the ankle or by Whitman in his operation of astragalectomy. The authors prefer the oblique dorsolateral incision of Hoke.

A. Approaches to the Tarsus.

1. Dorsolateral approach (Hoke).

a. *Indications.* (1) Triple arthrodesis in fractures of the talus or calcaneus, (2) exposure for reduction of fractures of the head and neck of the astragalus, (3) stabilization in paralysis of the muscles of the foot, particularly in anterior poliomyelitis.

b. *Position of the Patient.* The patient is supine with a sandbag under the hip on the affected side in order to internally rotate the extremity and present the lateral surface of the foot and ankle. The mesial surface of the foot and leg is supported on sandbags

c. *Landmarks.* (1) Heel, (2) lateral malleolus, (3) head and neck of astragalus, (4) common extensor tendons, (5) sinus tarsi.

d. *Incision.* An oblique incision in the skin about 2 inches in length is made beginning over the neck of the astragalus just lateral to the common extensor tendons and extending obliquely backward and downward over the peroneal tendons. The incision centers over the sinus tarsi which is palpated as a depression beneath and in front of the lateral malleolus (Fig. 13-40A).

Under the skin and subcutaneous tissues are numerous veins of the dorsolateral venous anastomosis. These are ligated. Under the superficial fascia, the intermediate dorsal cutaneous branch of the superficial peroneal nerve is isolated and retracted medially. Sometimes it can be saved, sometimes it must be sacrificed. The cruciate crural ligament is split in the direction of its fibers.

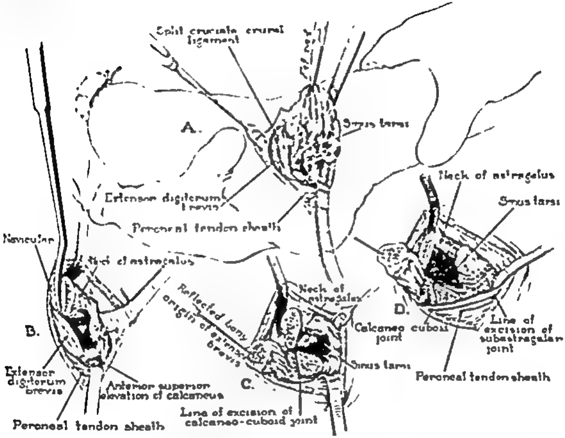

Fig 13-40 Triple arthrodesis (Hoke) A, through the oblique anterolateral incision, the ligaments and fat of the tarsal sinus are excised. B, the head of the astragalus has been removed and cartilage is being removed from the navicular bone C, the calcaneocuboid joint is revealed by horizontal osteotomy of the bony calcaneal origin of the extensor brevis. D, the subastragalar joint is seen posteriorly by retraction of the skin and periosteum. (Courtesy Dr. LeRoy C. Abbott and associates)

To prevent sloughing of the skin its margins are not undercut and dissected back nor is retraction permitted on the skin edge alone. Exposure is obtained by lifting back the incised fascia and applying retractors only to the deep structures.

The fat and ligaments in the sinus tarsi are excised en masse by use of a sharp knife next to the bone. The anterior talofibular ligament and the capsule of the astragalonavicular joint are incised to expose the posterior, medial and anterior facets of the subastragalar joint and the astragalonavicular joint.

The neck of the astragalus is then osteotomized and the head is removed by freeing it from the capsule of the astragaloscaphoid joint. The cartilage is cleared from the navicular with a specially curved gouge (Fig. 13-40B). The posterior facet of the subastragalar joint is then exposed by subperiosteal reflection of the fibulocalcaneal ligament (Fig. 13-40D). The

cartilage is removed from both surfaces of the posterior facet with an osteotome. The sustentaculum tali is similarly dechondrified after a thin curved periosteal elevator has been placed around it to protect the structures on its inner margin. The calcaneal cuboid joint is exposed by horizontal osteotomy of the anterosuperior surface of the calcaneus. The origin of the extensor brevis digitorum muscle is then retracted forward and the joint surfaces are denuded of cartilage (Fig. 13-40C). The head of the astragalus is replaced after its cartilage has been removed. Its new position in relation to the neck of the astragalus varies depending upon the deformity which is to be corrected. In addition, backward displacement of the foot on the astragalus is generally performed to reestablish balance, particularly in paralysis due to anterior poliomyelitis.

The wound is closed by a few interrupted subcutaneous sutures, with interrupted vertical mattress sutures being used in the skin. It is necessary that the sutures be tied loosely to avoid skin necrosis. The foot is immobilized in a long-leg plaster cast extending from the toes to the upper thigh. This may be changed to a short plaster cast after two weeks, when the patient may get up on crutches without bearing weight on the foot.

2. Lateral malleolar approach of Whitman for astragalectomy.

a. *Indications.* (1) Calcaneal valgus, (2) equinovarus, (3) septic ankle joint.

b. and c. *The position of the patient and the landmarks are the same as those for the Hoke operation.*

d. *Incision.* Beginning an inch above and posterior to the external malleolus, the incision curves downward and forward along the course of the peroneal tendons to the level of the calcaneocuboid joint. The incision is deepened through the fascia to expose the peroneal tendons which are then retracted posteriorly or occasionally, if necessary, divided. This is done by opening the tendon sheath and sectioning the tendons obliquely below the external malleolus. Care is taken here to preserve the short saphenous vein and the sural nerve which lie posterior to the peroneal tendons and external malleolus. The sinus tarsi, the head and neck of the astragalus, and the subastragalar and astragalonavicular joints are exposed, and the ligaments holding the astragalus at the ankle, astragalonavicular and subastragalar joints are severed. Inversion of the foot brings the astragalus into the wound so that the attachment of the transverse fibers of the deltoid ligament can be sectioned along with separation of the capsule from the astragalus at the medial border of the subastragalar joint. The astragalus is then removed.

To construct a new ankle joint, the malleoli are tailored to fit in the midtarsal region. The medial malleolus, after appropriate trimming is placed in the space which was occupied by the head of the astragalus. The tip of the external malleolus is mortised into the lateral part of the calcaneocuboid joint. This procedure usually gives a stable joint with a useful range of motion. Backward displacement of the foot on the leg is an essential feature of the operation

This approach of Whitman is similar to the Kocher approach used for drainage of the ankle. Astragalectomy, however, with fixation of the

foot in a position of inversion gives more complete drainage in severe and widespread infection of the ankle joint, and by its use in such cases amputation may be avoided.

3. Dorsal approach to the tarsus (Abbott).

a. *Indications.* (1) Metatarsus varus with bony deformity, (2) injury and disease requiring extensive exposure of the tarsal and tarsometatarsal joint.

b. *Position of the Patient.* The patient is supine on the operating table with the knee supported on pillows at an angle of 45 degrees of flexion. A small sandbag is placed under the forefoot holding the ankle at a right angle.

c. *Landmarks.* (1) Cuneiform-metatarsal joint, (2) tendon of the extensor hallucis longus muscle, (3) calcaneocuboid joint.

d. *Incision.* A 5-inch, slightly curved incision through the skin with its convexity facing distally is made across the dorsal surface of the foot. It begins medially at the first cuneiform-metatarsal joint over the tendon of the extensor hallucis longus muscle and ends over the calcaneocuboid joint about ½ inch above the sole of the foot. The incision is deepened through the superficial fascia which is incised transversely. The deep fascia covering the tendons of the extensor digitorum longus and extensor digitorum brevis muscles is preserved and the dorsal cutaneous nerve of the foot is isolated and protected except for the severance of a small twig which is cut as it passes medially across the arch of the foot.

At the inner part of the incision the tarsus is exposed in the interval between the extensor hallucis longus tendon and the fleshly substance of the extensor digitorum brevis muscle. The dorsalis pedis artery and the deep cutaneous branch of the peroneal nerve lie in this interval. The artery is identified and retracted medially with a vein hook along with the tendon of the extensor hallucis longus muscle. The nerve is retracted with the belly of the extensor digitorum brevis muscle. This exposes the capsule of the first metatarsal cuneiform joint and on proceeding laterally the mesial and lateral borders of the origin of the extensor digitorum brevis are identified and elevated with a periosteal elevator. A loop of gauze to act as a retractor is then passed around the extensor digitorum brevis muscle, the extensor hallucis longus tendon, and the superficial and deep cutaneous nerves. By retracting this mass to either one side or the other, the dorsal surface of the tarsus can be uncovered and brought into view.

With a broad curved osteotome the metatarsocuneiform joints are now unroofed by cutting a single section of bone which includes in one piece the dorsal cortices of the three cuneiforms and the bases of the second and third metatarsal bones This section of bone is then turned upward and outward, the periosteum and ligamentous attachments over the superior and lateral surfaces of the calcaneocuboid joint being used as a hinge. In this way the calcaneocuboid joint is exposed. This dissection provides access to both the metatarsocuneiform and calcaneocuboid joints so that reconstructive procedures for correction of deformity of metatarsus varus, or other operations which may be indicated in this region can be carried out. On closure of the wound the lid is replaced and fixed with

sutures which preserves the gliding surface for the tendons on the dorsal surface of the foot.

4. Approach to the astragalonavicular and naviculocuneiform joints.

a. *Indications.* (1) Injury, (2) infection, (3) pronation of the foot.

b. *Position of the Patient.* The patient is supine with the affected knee supported in a position of 90 degrees flexion and the foot resting across the other leg.

c. *Incision.* These two joints are generally approached by a median incision which passes through the skin and subcutaneous tissues to the level of the periosteum and joint capsules connecting these bones. Superiorly lie the tendon of the tibialis anticus, the extensor hallucis longus muscle, the deep peroneal nerve and the dorsalis pedis artery. Posteriorly and inferiorly lie the tendon of the tibialis posticus muscle and its insertion into the tarsus. The saphenous vein and the saphenous nerve and their branches should be looked for on the medial aspect of these joints and retracted to either side of the wound.

The astragalonavicular joint is exposed by longitudinal or vertical incision of the capsule. The naviculocuneiform joint is exposed by subperiosteal reflection on its dorsal and plantar surfaces. Exposure of the latter joint is most frequently necessitated by an operation for pronation of the foot, such as that devised by Hoke in which a fusion of the naviculocuneiform joint is done by removal of its cartilage and by countersinking a bone graft taken from the tibia across the joint line.

B. Approaches to the Metatarsus and Phalanges.

1. Dorsal approach to the metatarsophalangeal joints.

a. *Indications.* (1) Hallux valgus and hallux rigidus, (2) arthritis, (3) fractures.

b. *Position of the Patient.* The patient is supine with the knees flexed on pillows.

c. *Landmarks.* (1) Metatarsophalangeal joints, (2) intermetatarsal spaces.

d. *Incision.* The metatarsophalangeal joints are exposed by dorsal longitudinal incisions over the interval between the heads of the metatarsals. The digital vessels with their accompanying nerves are retracted to either side with the extensor tendon to expose the capsule of the joint. This type of incision is employed by Stein and others for correction of hallux valgus. Medial and dorsomedial incisions are also employed for correction of hallux valgus, particularly when osteotomy is to be performed on the neck of the first metatarsal or the base of the first phalanx.

2. Dorsal approach to the interphalangeal joints of the toes. This is commonly used for correction of hammer toe. Through a transverse elliptical incision over the dorsum of the proximal interphalangeal joint of the toe, the callus, the dorsal capsule, the extensor tendon and the cartilaginous surfaces of the joint are excised. The denuded bone surfaces are then approximated and the toe is held straight while sutures are placed which unite the cut edges of the capsules and the ends of the extensor tendon. Additional fixation may be secured by transfixation of the joint with a Kirschner wire.

The authors wish to express appreciation to Ralph Sweet and Joseph Yuhasz for the illustrations, and to Patricia Gallagher and Eleanor Little for editorial assistance.

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14

THE ORTHOPEDIC SURGICAL TREATMENT OF SPASTIC PARALYSIS AND ANTERIOR POLIOMYELITIS

FREMONT A. CHANDLER

SPASTIC PARALYSIS

The term "spastic paralysis" refers to a greatly varied symptom complex, in which the hypertonicity of the skeletal muscles and distorted muscle control are the outstanding features. Because of the wide variety of classifications, considerable confusion has resulted in the various terminologies. By general usage, the term "spastic paralysis" is applied to that paralysis resulting from birth injury or prenatal pathology. In this chapter, however, the spastic picture following trauma or the result of other pathologic processes will likewise be discussed.

The statements made by W. J. Little in 1843 in his publication, *Nature and Treatment of the Deformities of the Human Frame*, still hold true:

"The effects of the derangement of the brain or cord may be limited to the functions of a single muscle,. . .or a larger number of filaments and more muscles may be affected...

"May present itself as a congenital affection or as a result of disease during infancy. It is often difficult and sometimes impossible to discriminate....

"In some instances, however, the weakness of intellect appeared to result less from permanent injury to the brain than from want of sufficient training and education....

"The deteriorated health of the parent had directly impaired the nutrition of the fetus, and both directly and indirectly the healthy development of the nervous system....

"An infant prematurely born,... inadequately prepared to contend against the operation of external agents... altered function, congestion, or disease of the most susceptible of the infant's organs, those of the nervous system should occur."

In general, spastic paralysis or Little's disease may be described as a disease, congenital or acquired, resulting from sclerosis of cells of the upper motor neuron, varying in degree and usually causing a hypertonicity of the muscles of the part affected. Orderly inhibitory stimuli of central origin do not reach the primary reflex arcs. In contrast to the more or less constant picture of hypertonic muscle reaction are the bizarre entities which we group under the general term of choreo-athetosis. In these, control of purposeful motion is distorted. Little's disease presents a picture of disturbed function of the corticospinal (pyramidal) tracts whereas the

latter group presents disturbed function of the tracts from basilar nuclei (extrapyramidal) tracts. An overlapping of these clinical pictures occasionally occurs.

The gross and histopathology of spastic paralysis which has been described by many writers may be summarized as follows: When associated with brain injury the lesion is usually found located on one or both sides of the brain and consists of sclerosis or softening of the area involved, resulting in a degeneration of the cortical spinal tracts. When due to arrested development, the gross evidence is prominent in the cortex as shown by a more primitive convolution pattern. Frequently, this is absent and the pathologic picture is present only on microscopic examination. When associated with a disease such as syphilis, there is an associated meningomyelitis of vascular origin with a resulting scarring and adhesions of the membranes and invasion of the brain and cord substance.

When seen at postmortem, the brain surface presents a picture of neuroblastic death as evidenced by atrophic sclerosis and degeneration of the brain substance as a secondary gliosis.

1. A localized lesion of the brain cortex or a small lesion involving the converging cortical spinal tract at or near the internal capsule. These small localized lesions will give focal symptoms involving one or part of any of the extremities and trunk.

2. Scattered pathology. This is chiefly prefrontal in origin or in the temporal or parietal lobe and is more frequently associated with gross mental defects.

3. A diffuse (walnut) brain in which the front and occipital gyri are hard, shrunken and leathery. The cerebellum is usually normal. It may be associated with cavity formations within the brain substance or marked enlargement of the ventricles, probably a process which starts in the deeper cortical layers and is probably a manifestation of embryologic vascular rests.

4. Corpus striatum changes, confined to the caudate nucleus and putamen and the basal ganglia, causing bilateral athetosis and chorea. They are thought to be a prenatal process. A similar lesion in the premotor area is usually responsible for the choreiform athetoid movement found in so many spastics.

5. A vascular change is often encountered and is evidenced by scarring following a periarteritis or a cortical venous thrombosis.

Any one or all of the above complications may be present in the same individual, each resulting in a loss of the inhibitory section of the upper motor neuron.

The title of this chapter, "The Orthopedic Surgical Treatment of Spastic Paralysis," would better read, "Orthopedic Surgical Phases of the Treatment of Spastic Paralysis," for in the consideration of these pathetic patients the many other phases of treatment should be kept in mind. Surgery plays but a minor role, serving to overcome some of the otherwise insurmountable obstacles of the more normal development and functioning of the spastic patient. When confronted with a spastic patient, the orthopedic surgeon must control his urge to resort to surgery. He must evaluate the possibilities

of the improvement which always accompany growth, the potentialities of mental development, the general state of health of the patient and the possibilities of improvement under a strict regime of physical therapy. Other than in the rare instance where heroic measures are indicated to remove cerebral blood clots, no surgery should be resorted to until the patient reveals some manifestation of coordination of muscle action.

During this stage, which may last from a few weeks to several years, treatment should consist of general nursing and the *establishment* of a proper medical regime as well as properly directed physical therapy. Probably nothing is more important in this phase than the adjustment of the parents to the burden that confronts them. Firm but guarded assurance that muscle control will definitely improve with growth may be given. All reasonable attempts of improvement of nutrition and the correction of other pathology, such as pathologic tonsils, should be carried out. *Correction of ocular defects by the use of lenses is highly advisable* if the patient's condition will permit the wearing of glasses. In our clinic, all spastic cases are examined by the Departments of Ophthalmology, Pediatrics, and Neurology, and the results are most gratifying.

Open surgery is not indicated except for the correction of some definite obstacles to progress. As spontaneous muscular coordination advances, characteristic deformities become manifest. If these are constant and progressive in degree, their correction by surgery should be contemplated. Surgery in spastic paralysis should be carried out according to the following axioms:

1. The deformity or disability must be static, progressive or diminishing so slowly that recovery is not to be expected.
2. The disability must be constant in its manifestations.
3. The interrelationship of multiple deformities must be understood.
4. *The benefit to be had by surgery must justify the risk.*
5. Sufficient time must elapse between surgical procedures to permit the reestablishment of a constant clinical picture.
6. Methods of treatment other than surgical should not be neglected.
7. The patient should be fortified for surgery by every means possible.

Overactivity of the adductor muscles of the thighs is undoubtedly of first importance in its effect upon the function of the lower extremities. Scissors' gait or position of the legs is indeed an obstacle to progression as well as a definitely contributing factor to flexion deformity of the knee. Overactivity of the adductor groups is indirectly associated with the production of gross deformities of the feet, for with the foot fixed by weightbearing, adductor action results in pronation and a gradual breaking down of structures supporting the longitudinal arch. In extreme instances, this resultant force is reflected in the development of severe hallux valgus deformity. Each of these deformities is, of course, *influenced* by overactivity of the internal rotators and muscle imbalance about the knee and ankle as well. Because of the major importance of adductor overactivity in distorting the entire weightbearing line of the leg, correction is of first importance. In our experience, stretching of the adductor group of muscles

gives only temporary benefit at best. The same may be said of tenotomy or myotomy of the origin or upper part of the adductor groups. It is obvious that when contractures have developed rendering active or passive abduction impossible, surgical procedures must be employed. Conversion of the

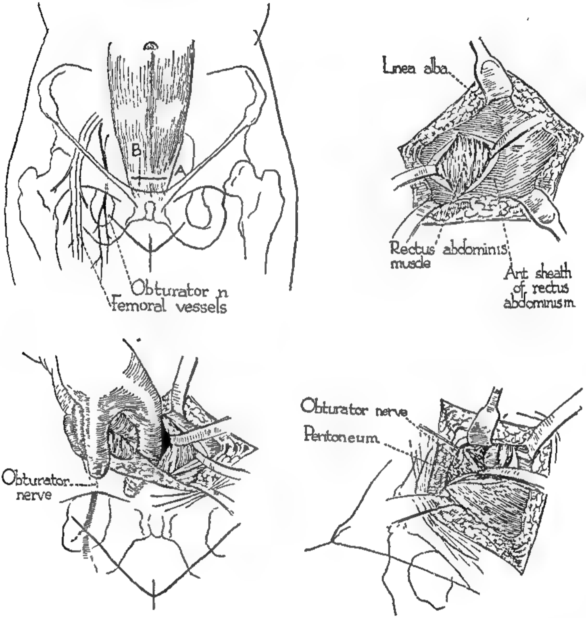

Fig. 14-1 Intrapelvic extraperitoneal resection of the obturator nerve in the treatment of spastic paralysis Top left, incisions A, skin incision (Pfannenstiel), B, incision of the anterior sheath of the right rectus abdominis muscle

Top right, exposure of the lateral margin of the right rectus abdominis muscle.

Bottom left, blunt extraperitoneal dissection with index finger along the posterior surface of the horizontal ramus of the pubis until the obturator nerve is palpated.

Bottom right, oblique view with peritoneum retracted medially to expose the right obturator nerve. (From Chandler and Seidler Surg, Gynec. & Obst., 69.100, 1939)

spastic paralysis of this muscle group to a flaccid paralysis by neurectomy is most beneficial. This is done most frequently by locating the anterior and posterior branches of the obturator nerve by dissection between the uppermost portions of the adductor longus and the pectineus. The anterior branch lies in front of the adductor brevis muscle while the posterior branch lies

behind it. If both of these branches are divided a satisfactory result is obtained. The posterior branch penetrates the external obturator muscle at various levels and because of this may be difficult to locate. Our results with this operation were fairly satisfactory. This procedure has been abandoned for the simpler and more uniformly successful resection of the main obturator nerve just proximal to the obturator fascia (Selig operation). This procedure is simple and most effective when carefully done.

In bilateral resections a transverse (Pfannenstiel) incision is made in the lowest transverse skin crease just above the pubis exposing the anterior sheaths of the rectus abdominis muscles (Fig. 14-1). The sheath of the rectus is then split vertically over the center of the distal portion of the muscle. The lateral portion of the rectus sheath is then reflected and the lateral margin of the muscle outlined. This is retracted medially. The index finger is used as a blunt dissector following the posterior surface of the rectus to its insertion in the horizontal ramus of the pubis, then more deeply and laterally displacing the bladder and peritoneum posteriorly until the obturator nerve is palpated as it lies within the pelvic wall. Flat retractors are then inserted and the fatty areolar tissue is gently opened. The nerve is easily located and may be identified by its position as it enters the neural foramen of the obturator fascia or by stimulation of the nerve. The nerve is then separated from the blood vessels that accompany it by means of a blunt hook. A ligature is placed at each of two levels along the nerve and a section of the nerve is excised. Care must be taken not to tear any of the many small veins, and the possibility of anomalous arteries should be kept in mind. The peritoneum is permitted to fall back into place and the rectus fascia and skin sutured. No cast or apparatus is employed. In a consecutive series of resections of over 200 nerves by this method, no complications of any nature have developed. The relaxation of the adductor group in this manner is more satisfactory than other methods we have employed. In no case have we had abduction deformities develop. Some adduction persists due to secondary innervation from the sciatic nerve.

Flexion deformity of or inability to extend the knee completely is next in importance. Here again, stretching is of only temporary benefit and more radical measures are justifiable. Lengthening of the hamstring muscles, stripping of the posterior capsule, supracondylar osteotomy, or neurectomy of the hamstring branches of the sciatic nerve may relieve the active deforming factor in properly selected cases. Too frequently, however, complete active extension with or without weightbearing is lacking even though passive extension of the knee is possible. In many of these cases an abnormally high position of the patella is found. In order to lower the patella to position at the level of the knee joint, the insertion of the patellar tendon is transplanted distally on the anterior aspect of the tibia. In some cases in which the spasm of the quadriceps is especially pronounced, difficulty in maintaining the reinsertion has been encountered. Several valuable suggestions have been made to improve the original technic. Carrell encircles the patella with wire which is fixed to the tibia. Burns transfixes the patella with a Kirschner wire and fixes it in the cast so as to aid in maintaining advancement. Many other possible

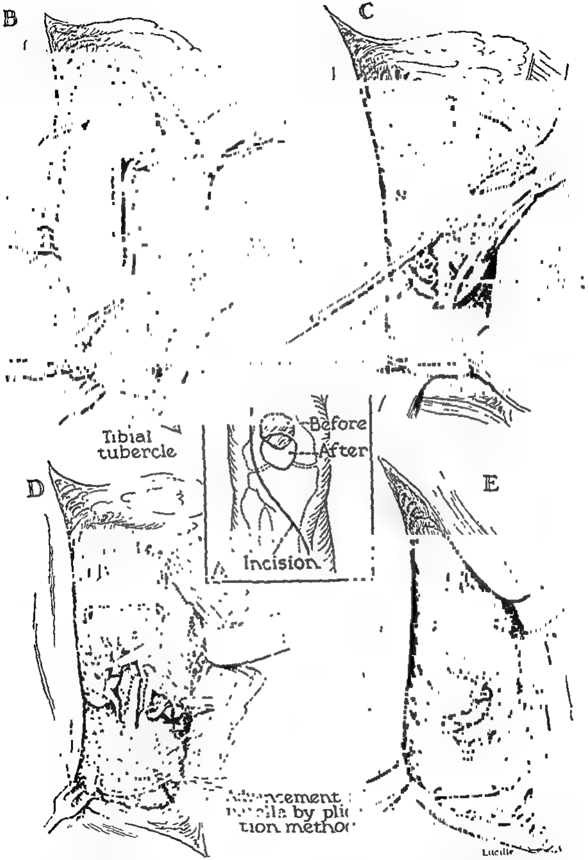

Fig. 14-2. Advancement of the patella by plication method A, incision. B, the patellar tendon is [illegible] in the midline and narrow strips are cut from the free margins as indicated. C, a [illegible] cable is passed through the holes that have been drilled through the pat[illegible] just below the tubercle, and the wire is drawn taut, bringing the patella in [illegible] in relation to the joint D and E, the strips of tendon are laced through [illegible] of the patellar tendon and anchored (From Chandler J. Internat. Coll. [illegible])

variations of technic are obvious (Fig. 14-2). The possibility of arrested growth of the anterior portion of the upper tibial epiphysis must not be overlooked. This is especially true if this operation is undertaken in young children. A plastic operation on the patellar tendon will accomplish advancement more safely. Cleveland, Wagner, Heyman, and Speed and many others have reported successful results with the basic principle of patellar advancement. Transplantation of the biceps tendon to the patella has been practiced widely, but this should supplement patellar advancement to give the best results.

Equinus deformity of the foot comes next in importance in the consideration of spastic disabilities of the lower extremities. The relation of this deformity to the stabilization of the knee must be kept in mind. Lengthening of the tendo achilles results in good correction in many cases but in others shows greater disability. Resection of the motor branches of the popliteal nerve is also effective, but difficulty is encountered in estimating the extent of neurectomy. A fixed equinus deformity is frequently observed when the knee is held extended although a satisfactory dorsiflexion is obtained when the knee is flexed. This indicates a contracture of the gastrocnemius portion of the calf rather than of the entire calf group. Sherb recognized this fact and in 1935 published a paper describing an operation of multiple fasciotomies of the fascia of the gastrocnemius muscle. This procedure has been called the herringbone fasciotomy because of the alternating incisions used in lengthening this fascia. The large amount of muscle tissue in the soleus renders it more susceptible to stretching as compared with the gastrocnemius which has a large fascial element.

H. A. Durham reported a simple but effective operation to correct *internal rotation of the thigh*. In this, the anterior portion of the gluteus medius is divided at its insertion into the greater trochanter. A cast holding the legs externally rotated is employed postoperatively.

Instability of the foot presents a greatly varied problem, and methods of correction should be adapted to each individual deformity. In our experience, tendon transplant alone does not prove as satisfactory as when combined with arthrodesis of the posterior tarsus. In equinovarus deformity, lengthening of the posterior tibial tendon is helpful. Reinsertion of the anterior tibial tendon into the dorsum of the tarsus has given good results in a small number of cases. Overactivity of the peroneus longus muscle with valgus deformity of the forefoot responds favorably to lengthening of the peroneal tendon combined with a medial cuneiform osteotomy which includes the scaphocuneiform joint. The relation of adductor spasm of the hip to this particular deformity bears reemphasis.

Correction of *extension deformities of the toes* should not be attempted until the tarsus itself is properly corrected. Insertion of the long toe extensors into the metatarsals is the procedure of choice (Fig. 14-3). Arthrodesis of the interphalangeal joint of the first toe is done to prevent and correct hammer toe deformity (Fig 14-4).

Disability due to *spastic paralysis of the upper extremity* resists correction to a much greater degree than that of the lower. This is probably due to the finer movements which normal function implies as well as the greater degree of nonuse that occurs in the upper extremity in the

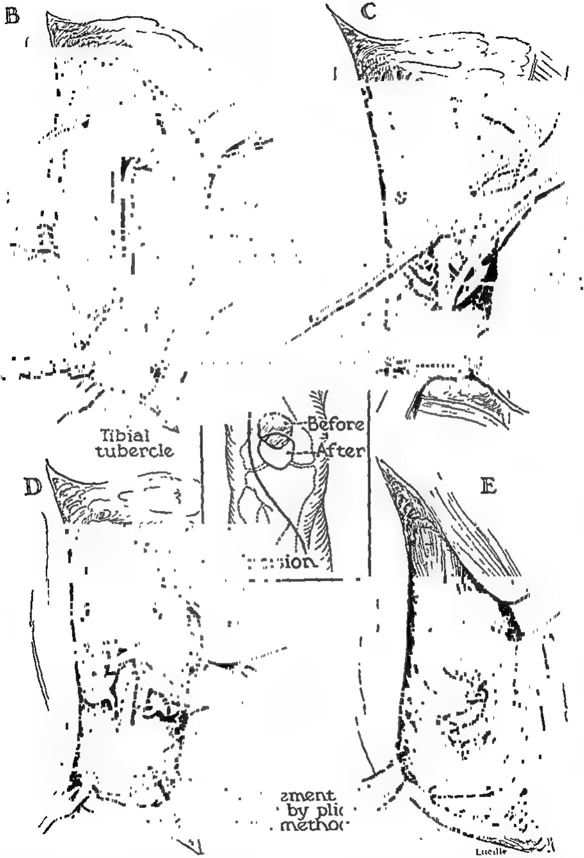

Fig. 14-2. Advancement of the patella by plication method. A, incision B, the patellar tendon is incised in the midline and narrow strips are cut from the free margins as indicated. C, a loop of airplane cable is passed through the holes that have been drilled through the patella and the tibia just below the tubercle, and the wire is drawn taut, bringing the patella into normal position in relation to the joint D and E, the strips of tendon are laced through the redundant margins of the patellar tendon and anchored. (From Chandler. J. Internat. Coll. Surgeons, 3:434, 1940)

presence of any malfunction. Pronation deformity of the forearm associated with flexion deformity of the wrist is usually the outstanding deformity.

Treatment of this condition by constant stretching and splinting is discouraging, and surgical measures are justifiable. An understanding of the interrelationship of these deformities is essential. An attempt at correction of the pronation of the forearm without correction of the wrist deformity invites failure, for the flexed wrist and dependent hand act to pronate the forearm when the patient is in the upright position, thereby offsetting the benefits of any correction that may have been accomplished.

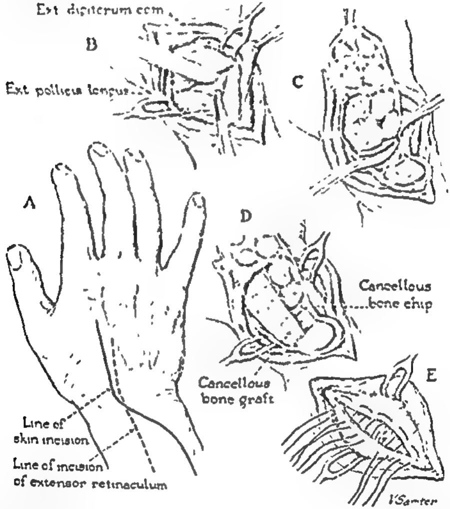

Fig 14-5 Wrist fusion with iliac graft to stabilize joint. A, line of incision. B, opening into joint. C, preparation of bed for graft D, insertion of bone grafts. E, closure of joint capsule with fine silk.

Correction of flexion deformity of the wrist is therefore the key to this complex disability. This may be accomplished by transplantation of the carpal flexors to the extensors or better, especially in older patients, by arthrodesis of the radiocarpal articulation holding the hand in 15 to 20 degrees of extension. Due to the presence of motion between the carpal bones, wrist fusion alone is only partially successful To obviate this factor, we have used a heavy cortical graft inserted subperiosteally on the dorsum of the radius, bridging the wrist joint and fixed in a deep cleft in both rows of carpal bones, at times reaching to the metacarpals (Fig. 14-5). This graft is effective in immobilizing the wrist as well as the carpus itself. The

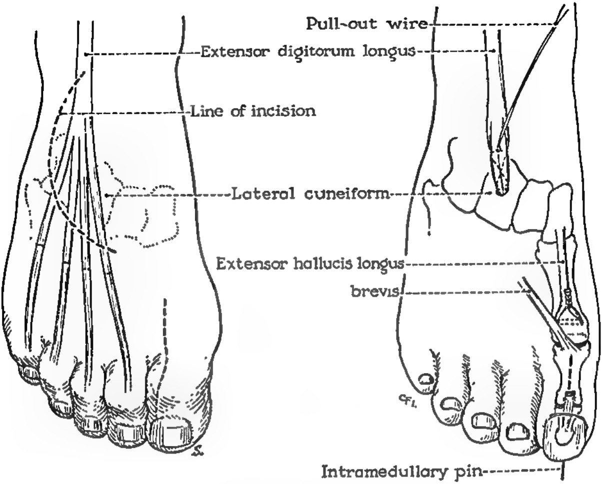

Fig 14-3. For correction of clawtoes and pes cavus, the Hibb's operation is described: the tendons of the extensor digitorum longus are inserted as a group into the lateral cuneiform (Cole), the extensor hallucis longus is inserted into the head of the first metatarsal; the interphalangeal joint is fused, using internal fixation (From Campbell, W. C. *Operative Orthopedics*, 2nd ed., 1949. Courtesy C. V. Mosby Co.)

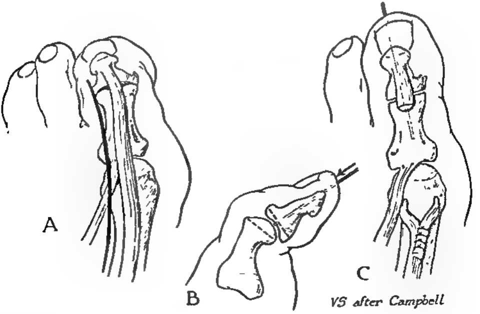

Fig 14-4 Correction of hammer toe of hallux. A, anatomic relations of tendons and phalanges. B, resection of interphalangeal joint and fixation with steel pin. C, transplantation of extensor hallucis longus to head of first metatarsal

presence of any malfunction. Pronation deformity of the forearm associated with flexion deformity of the wrist is usually the outstanding deformity.

Treatment of this condition by constant stretching and splinting is discouraging, and surgical measures are justifiable. An understanding of the interrelationship of these deformities is essential. An attempt at correction of the pronation of the forearm without correction of the wrist deformity invites failure, for the flexed wrist and dependent hand act to pronate the forearm when the patient is in the upright position, thereby offsetting the benefits of any correction that may have been accomplished.

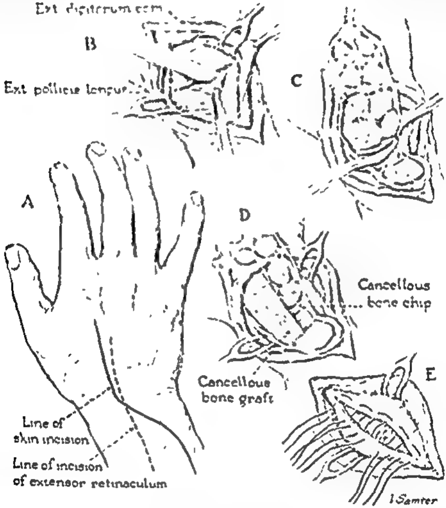

Fig 14-5. Wrist fusion with iliac graft to stabilize joint A, line of incision. B, opening into joint C, preparation of bed for graft. D, insertion of bone grafts. E, closure of joint capsule with fine silk.

Correction of flexion deformity of the wrist is therefore the key to this complex disability. This may be accomplished by transplantation of the carpal flexors to the extensors or better, especially in older patients, by arthrodesis of the radiocarpal articulation holding the hand in 15 to 20 degrees of extension. Due to the presence of motion between the carpal bones, wrist fusion alone is only partially successful. To obviate this factor, we have used a heavy cortical graft inserted subperiosteally on the dorsum of the radius, bridging the wrist joint and fixed in a deep cleft in both rows of carpal bones, at times reaching to the metacarpals (Fig. 14-5). This graft is effective in immobilizing the wrist as well as the carpus itself. The

function of the fingers is greatly enhanced by the improved position of the wrist. With the wrist in good position, correction of the pronation may be accomplished by division of the pronator teres and pronator quadratus, or possibly by converting the pronator teres into a supinator (Tubby operation). Our results in section of the branches of the median nerve have been uniformly poor.

We have had little occasion to employ the thumb check operation (Fig. 14-6) or alter the function of the finger flexors by tendon lengthening. Deformities of the shoulder and elbow rarely necessitate surgical intervention.

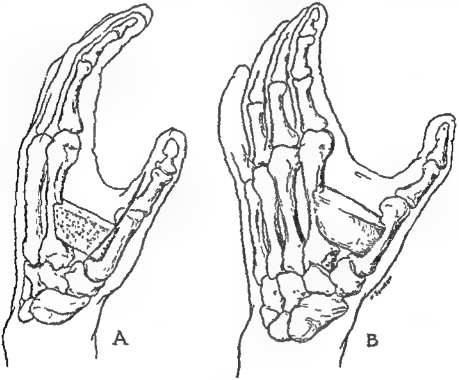

Fig 14-6 Fixation of thumb in position to oppose fingers. A, iliac graft. B, tibial graft.

In spastic paraplegia resulting from permanent cord damage of acquired nature, similar surgical procedures have been employed. The extraperitoneal obturator and popliteal neurectomies are most useful. The sensory and trophic changes which accompany these types of pathology limit the scope of surgery considerably.

Choreo-athetosis is probably the most distressing clinical entity met in dealing with spastic paralysis in the wider meaning of the term. These patients, who are of more normal mentality than are those of Little's disease, present an ever varying picture of irregular muscular control involving a single extremity or all of the body. Distortion of function of the facial muscles associated with attempts of speech are especially distressing. No consistency of disability is present and, therefore, most usual surgical procedures are of little or no avail. Intensive physical therapy carried out along the usual line of repeated exercises intensifies the condition rather than improves it. A large variety of drugs have been employed in treatment without distinct results. Occasionally improvement in gait follows stabilization of the feet. This is due to the lessening of effort in the

maintenance of balance and the relative simplification of pattern of nerve stimuli. The bizarre ineffective movements are best explained by altered stimuli arising in the basilar nuclei, especially Deiters' nucleus and the red nucleus as well as in corpus striatum. The majority of these efferent stimuli pass along the rubrospinal tract which lies deep in the anterolateral portion of the cord. Putnam approached this problem by dividing the rubrospinal tract by anterolateral cordotomy. His results were encouraging. Stimulated by his report, we selected seven cases of choreo-athetosis for a trial of this procedure. Dr. Eric Oldberg performed cordotomies high in the cervical cords of these patients with definite but limited improvement in all cases. I have followed these cases to date and feel that the procedure fully justifies the risks involved. This type of surgery should be done by a well trained neurosurgeon rather than by one whose training has been in orthopedic surgery.

SURGICAL TREATMENT OF ANTERIOR POLIOMYELITIS

Anterior poliomyelitis is a neuromuscular disease caused by a filterable virus and is transmitted through contact or some insect medium. Much research has been carried on during the past decades and numerous facts and much data have been accumulated regarding this disease. This has been made possible by the public interest and support of nation-wide programs of investigation and the care of patients who are victims of this disease. Reference to the reports of research and of clinical studies reveal many new concepts of the etiology, mode of transmission and means of treatment and cure. Several general observations may serve as a summary revealing the general status of our knowledge of this disease as of this time.

The infection may be endemic or epidemic occurring more often during the late summer and early fall. The disease is undoubtedly many times more prevalent than statistics would indicate, for many individuals harbor the infection without any clinical manifestation and serve as carriers. This may account for the relative immunity of older children and adults who have established resistance early in life. Young children infected by more virulent strains of the virus constitute the majority of cases reported. In all probability the majority of mild cases are not recognized, and general statistics fail to reflect the true status of disease incidence. In the presence of definite paralysis, recognition of the disease becomes more accurate. Control of anterior poliomyelitis must come through the development of some form of vaccine and its effective employment as a means of immunizing the entire population. Of the various vaccines recommended and tried during the past several years, the Salk vaccine offers the most promise and in fact has been reported as very effective after an extensive study.

Although the infection may well be classified as a general infection and the virus recoverable from many and varied tissues of the body, the chief site of pathologic changes are in the central nervous system, especially in the region of the anterior horn cells of the cord or the basilar region of the brain. The cells of the anterior horn may escape any real

damage and the disease run its course without any apparent loss of neuromuscular function, the nonparalytic type of the disease.

A second and somewhat greater degree of cellular involvement may occur wherein the cells are so damaged as to result in a temporary loss of function eventually recovering with restoration of the integrity of the neuromuscular system and recovery. The fact that recovery is manifest to varying degrees in the great majority of cases indicates a remarkable local resistance and potential reserve of the cells of the anterior horn.

A third degree of involvement occurs, in which complete destruction of the neuromuscular component is present and the pathologic changes are irreversible. In this group permanent paralysis of the flaccid type persists.

Treatment in group one consists of general measures of combating the disease with every means we have at hand, fully realizing that as yet we have no specific drug. Moist heat or baths are helpful and should be employed according to some of the popular technics. Gentle passive motion within the limits of pain are advantageous. The careful encouragement of voluntary movements is indicated. Many drugs have been employed but none has found wide acceptance. These should be used with caution, if at all.

These measures must be adapted to the specific needs of the patient. Movements through the normal joint range should be carried out if pain permits so as to prevent secondary changes of muscle and fascia, which result from local irritation or disease. Most patients will show considerable improvement within the first two or three weeks, indicating the recovery of the function of the anterior horn cells of the cord.

Considerable controversy has arisen regarding to use of splints during the first two stages of the disease. It is reasonable, however, to prevent stretching of weakened muscles by the use of a bed board, a foot board, or a more specifically designed splint in these cases. Splinting is for protection only and should not be overdone.

The second stage, which is usually designated as that period immediately following the subsidence of muscle tenderness, necessitates intensification of attempts to restore active use of muscles by well directed physiotherapy, hot packs, baths, gentle massage, etc. It must be remembered, however, that recovery is dependent upon the recovery of the damaged motor cells of the cord and that treatment has little to do in the reversal of this pathologic process.

The rate of the return of function, under skilful guidance, will provide a good basis for the ultimate prognosis. If recovery is definite and progressive, the prognosis is good If slow and indefinite, the prognosis is less favorable. One accustomed to supervising polio cases can project a good estimate of the degree of permanent loss of muscular function that will result from the course of the disease. During the recovery period, braces may be employed to assist active function, but too much reliance on external support may delay such return Such apparatus must be used in definite relation to the needs of each particular case.

At the conclusion of 18 months to [illegible] years following the onset of the infection, recovery is nearly complete and an accurate picture of the residual

loss of muscular function may be had. At this stage evaluation of various surgical measures as means of lessening the handicaps should be entertained.

The fact that most of the victims of polio are children presents the problem of subsequent growth and the disturbances which result from loss of muscle action. With few exceptions surgery should be postponed until growth is nearly complete. Braces should be employed as aids to function during this period if possible. These should be light in weight but efficient so as not to add to the load of the extremity and its weakened musculature.

The *basic principles of surgery* as applied to cases of residual paralysis in anterior poliomyelitis consist of: 1, restoration of muscular balance; 2, stabilization of joints; and 3, realignment of skeletal structures.

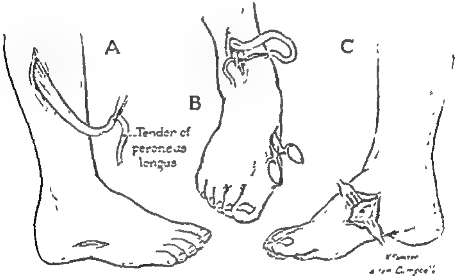

Fig 14-7. Transplantation of peroneus longus tendon to replace anterior tibial muscle function (Mayer)

1. Restoration of Muscular Balance. Deformity of a joint commonly is the result of alterations in the relative balance of opposing muscle groups. An overactive flexor group will result in flexion deformities, while overactive extensor groups will result in over-extension deformities. The same may be said of the imbalance of adductor and abductor group, internal and external rotators, etc. The less complicated deformities are present when single opposing muscle groups are involved. Complicated deformities result from a large number of muscle groups unbalanced in their action and the variety of joints involved. Deformity also results from an additional deforming force superimposed upon the action of muscles. This force is that of gravity acting directly on the joint structures or indirectly upon them through weightbearing. An example of the former is seen in the development of an equinus deformity at the ankle when the foot is permitted to drop and the calf muscles to contract. The later or secondary deformity resulting from gravity is seen in the development of equinus deformity of the foot itself in the presence of a weak calf group, due to the loss of opposition to the flexors of the forefoot. Deformities of both these types may be prevented or minimized by proper bracing through the growth period.

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At the conclusion of 18 months to 2 years following the onset of the infection, recovery is nearly complete and an accurate picture of the residual

Transplantation of the origins of the hamstring muscles to the patella is effective in selected cases (Figs. 14-8 and 9). In this operation a negative phase is accomplished by removing the flexing force acting on the knee joint and a positive phase by transferring these muscles to the extensor aspect of the knee. Here again the mechanical advantage of transplanted hamstring muscles cannot approach that of the normal quadriceps group. This operation is indicated in flexion deformity of the knee due to strong unopposed action of the hamstring group. In instances of lesser imbalance the biceps alone may be transferred anteriorly (Fig. 14-10).

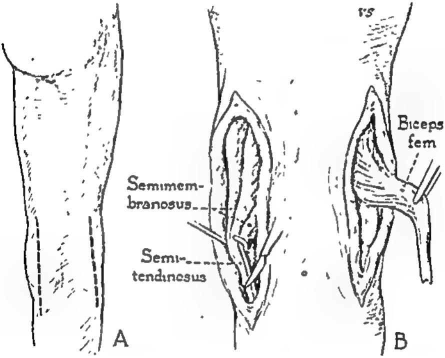


Fig 14-9. Tenotomy of one or more of the hamstring tendons to correct flexion deformity of knee Resected tendons are transplanted to patella to replace or supplement weak or paralyzed quadriceps muscle.

At the hip, muscle transplants have not been particularly successful. The replacement of a paralyzed gluteus medius muscle by the tensor fascia lata will add some power of abduction at the hip but it is rarely strong enough to withstand the adduction force resulting from weightbearing through the hip joint.

Weak abdominal musculature lends itself to reinforcement by the placement of strips of fascia lata to replace the weakened area (Fig. 14-11). This fascia is fixed to the lower ribs and iliac crest and may be attached to the more active abdominal muscle group of the opposite side, thereby transferring some positive muscle action.

Transplantation of muscles of the upper extremity are more effective than that in the leg and foot because of the absence of weightbearing. In flail elbow where flexion is lost, a good result may be expected by the advancement of the origin of strong finger and wrist flexors from the medial epicondyle of the humerus to a point one or one and a quarter inches higher on the humerus (Fig. 14-12). When the fingers and wrist are

A more permanent restoration of balance necessitates surgery. Theoretically the strong flexors of the forefoot (peroneus longus and posterior tibial muscles) can be transplanted to the tendo achilles, replacing the paralyzed calf group in calcaneo cavus deformity. This procedure is effective to a limited degree, but it is inconceivable that these transplanted muscles can ever attain the size and strength of a normal calf group.

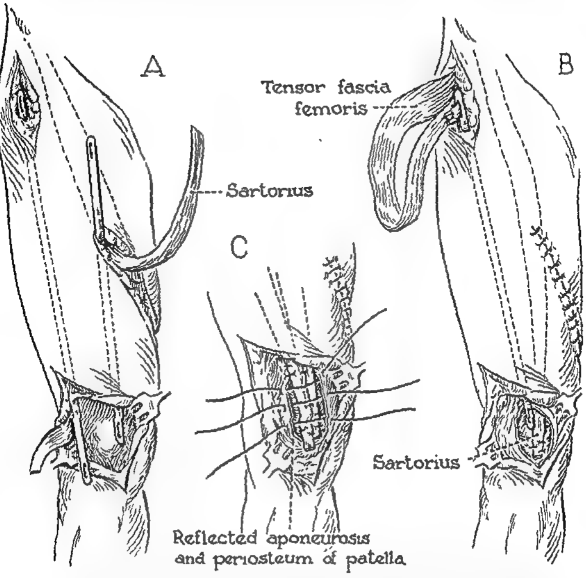


Fig. 14-8 Transposition of the tensor fascia lata and the sartorius insertion to strengthen extension of the knee A, through incisions at the level of the anterior to the greater trochanter and lateral to the patella, using a fascial stripper, a strip of fascia lata is freed distally, remaining attached proximally Through an incision over the anteromedial aspect of the distal third of the thigh the sartorius is exposed and severed from its insertion B, both the fascial strip and sartorius are passed subcutaneously to emerge over the patella. C, these are then sutured to the periosteum and fascia overlying the patella (From Barr First Internat. Polio Conf., 1948.)

Transplantation of the long toe extensors will lessen the tendency to hammer toe deformity and may become fairly effective in replacing the lost action of the anterior tibial muscle (Fig. 14-7).

Should the extensor hallucis longus be employed for this purpose, the interphalangeal joint of the first toe should be ankylosed in extension or a marked flexion deformity will result

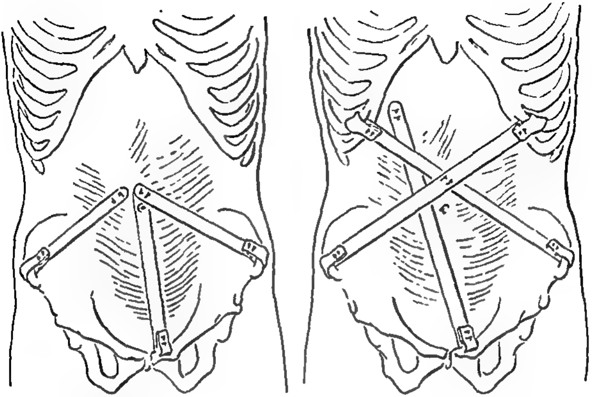


Fig. 14-11. Strips of fascia lata may be used to stabilize a paralyzed abdominal wall (After Wallace and West J Bone & Joint Surg., 29:1031, 1947.)

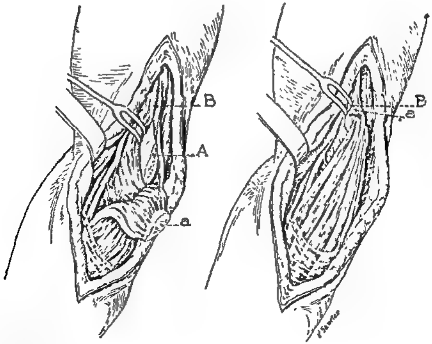


Fig 14-12 Advancement of internal epicondyle of humerus with origin of flexor muscles of hand and fingers to replace or supplement flexors of elbow (Steindler) A small segment of the internal epicondyle, a, is cut from its base, A, and transplanted to a new location 1 to 1½ inches higher up on the humerus at B

stabilized by their extensors, a resultant flexion force is exerted across the elbow joint and good flexion is possible. This is a most valuable procedure in restoring function to the arm and hand. The opposing force of extension is provided by gravity. In the polio hand restoration of opposition of the thumb is helpful (Fig. 14-13). This is accomplished by a wide variety of methods each adapted to the individual situation. The transplantation of the

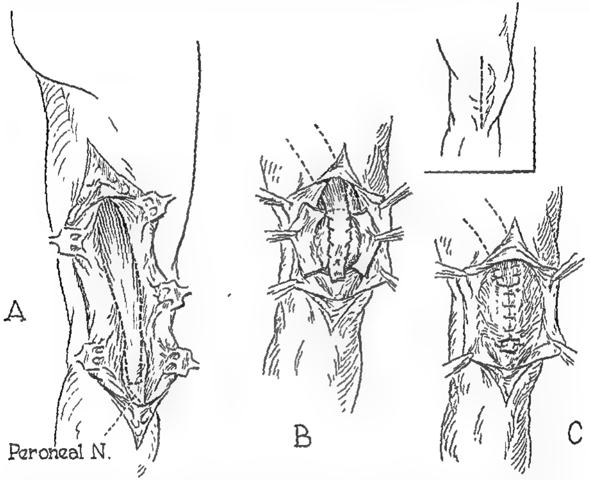


Fig 14-10 *Transposition of biceps femoris insertion to strengthen extension of the knee. A, through a posterolateral incision over the distal third of the thigh and the knee, the biceps femoris muscle and tendon are exposed. After identifying the common peroneal nerve, the tendon is severed from its insertion B, a curved lateral parapatellar incision is made and the biceps tendon is passed through a lateral subcutaneous tunnel to emerge through this second incision. The deep fascia over the patella is opened in a double trap-door fashion and the tendon is sutured to the periosteum as shown C, the biceps tendon is further fixed to the quadriceps tendon, and the previously incised fascia is sutured over the transplanted tendon. (From Barr First Internat Polio. Conf, 1948)*

palmaris longus to produce an opposing force to the thumb is most widely used. This tendon is cut at its insertion into the palmar fascia and attached to the outer margin of the proximal phalange of the thumb by a free tendon graft or by the tendon of the extensor pollucis brevis passing through a pulley at the pisiform bone or around the tendon of the flexor carpi ulnaris muscle. Contraction of the palmaris muscle results in opposition of the thumb as well as in rotation, permitting contact with the fingers. The tendon of the flexor carpi ulnaris may be used in a similar manner with satisfactory results (Fig. 14-14).

tion of the deltoid muscle retains its power and may be transplanted to a more advantageous position on the acromion process. The deltoid muscle shows good recuperative power even after long periods of apparent paralysis. The removal of the weight of the arm by the use of an abduction splint is indicated before any resort is made to surgery.

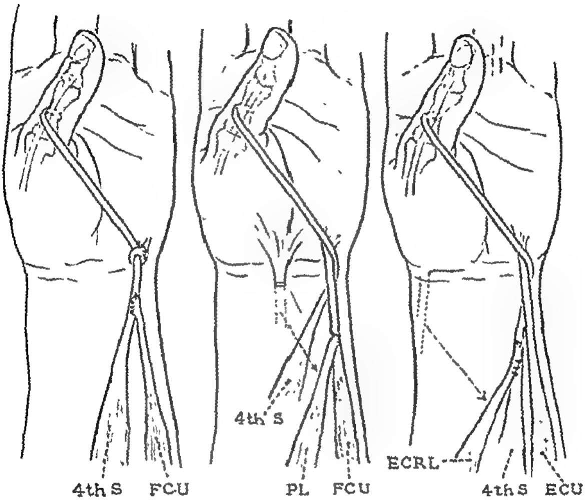
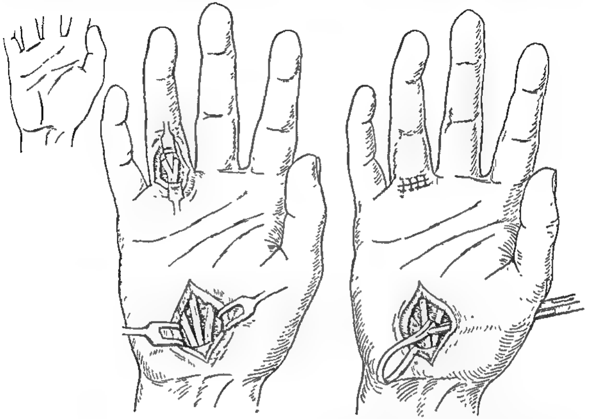


Fig 14-14 Restoration of opposition of the thumb. Left, the distal portion of the flexor carpi ulnaris tendon may be used as a static pulley, leaving this flexor muscle free to be combined with sublimis IV to strengthen the motor Center, a second motor, such as the palmaris longus, may be used to increase the stability of the pulley Right, the extensor carpi radialis longus tendon may be sutured to that of the sublimis IV tendon to increase the strength of the motor used to restore opposition of the thumb (From Irwin. Second Internat Polio. Conf, 1952.)

Muscle and tendon transplantation have a definite place in the surgery of polio but the results fall far short of those that might be expected on theoretical considerations. This is due to the complicated mechanical factors at the various articulations. Muscle transplantation done in conjunction with joint stabilization enhances the result considerably, especially in the lower extremity.

2. **Stabilization of Joints.** The stability of any joint is an important factor in its function. Much of this stability depends on muscle tone and ligamentous integrity In the absence of these the fulcrum of movement becomes uncertain and the action of muscles less certain. In polio, with its residual disturbance of motor power, stability of joints becomes an

No fixed rules can be laid down for the restoration of finger function for each case varies considerably as to available motor sources and must be evaluated accordingly. Probably no phase of surgery will tax the ingenuity of the surgeon more than the hand affected by polio. Reference to texts on hand surgery is recommended.



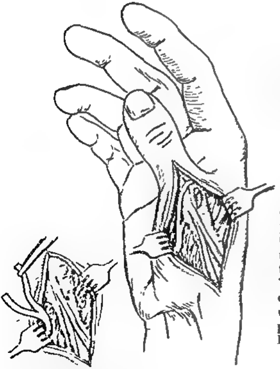


Fig 14-13. Transplant of flexor sublimis III to restore opposition of the thumb (Thompson-Royle) Top left, through an incision in the proximal phalangeal flexor crease, the flexor tendons are exposed and the sublimis tendon is severed as demonstrated. Through an incision in the longitudinal midpalmar crease, the flexor tendons are exposed as they emerge from the carpal tunnel. Top right, the severed tendon is identified and retracted through the proximal incision It is then passed subcutaneously toward the first metacarpophalangeal joint and brought out through an incision over the dorsoradial aspect of the first metacarpal and metacarpophalangeal joint Bottom, the tendon is split longitudinally. One half is passed through a transverse drill hole in the neck of the metacarpal bone from radial to ulnar side and is sutured to the periosteum. The other half is passed over the dorsal aspect of the metatarsophalangeal joint, from radial to ulnar side, and sutured to the periosteum of the proximal phalanx on its ulnar side. (From Barr. First Internat. Polio Conf, 1948)

Residual paralysis at the shoulder does not lend itself to satisfactory transplantation of muscle action. The weight of the arm and the short leverage available mitigates against successful results. Occasionally a por-

The deformities of varus, valgus, calcaneus, cavus, equinus, and others, develop as a result of function imbalance in cases of residual paralysis in polio. Relaxation of ligamentous structures and increased mobility of the tarsal joints add to its instability. Adaptive changes in the conformation of the tarsal bones, resulting from malposition during the growth period, complicates the picture. Restoration of a more normal contour and elimination of abnormal mobility is essential. This is accomplished by osteotomy of the tarsal bones to correct skeletal deformity and by arthrodesis of varying numbers of tarsal joints (Fig. 14-15). The consolidation of the tarsus into a single bony structure simplifies the mechanics and gives stability. Many varied technics have been devised but the correction of deformity and the elimination of joint function are common to nearly all. Deformity is corrected by vertical or horizontal cuneiform osteotomies of the tarsal bones and arthrodesis by the removal of the articular cartilage between the astragalus, os calcis, scaphoid, cuboid and in some the cuneiform bones. A complete correction of any deformity is essential. The os calcis is rotated to a normal horizontal position, displaced posteriorly to increase the leverage of the calf muscle group. Excision of the scaphoid facilitates correction of cavus deformity permitting fusion of the head of the astragalus with the cuneiform bones.

The *tarsal joints are approached* through a single curved incision on the dorsolateral aspect of the tarsus or perhaps better to medial and lateral incisions. If the plantar fascia is short in cavus deformity it should be cut transversely just anterior to its origin (Fig. 14-16). Bone-to-bone contact is made at all excised joints, care being taken to avoid any undue tension on the various ligaments. The wounds are sutured and the foot encased in a circular plaster splint which is left in place for 12 to 14 days. The plaster splint, extending to the mid-thigh unless contraindicated, is split to remove pressure and the foot elevated to reduce swelling. At the termination of two weeks, a short leg splint is applied and worn until consolidation of the tarsal bones is complete (10 to 12 weeks). During the latter part of this period, weightbearing is permitted.

In some instances excision of the astragalus is indicated, the ankle mortice being engaged on the upper anterior aspect of the os calcis and cuboid. Astragalectomy applies particularly to calcaneus deformities (Fig. 14-17).

A good arthrodesis of the tarsus should result in a stable painless foot, well able to withstand weightbearing. Tendon transplantation may be done in conjunction with the bone work or as a separate procedure later.

In cases where *foot drop* is marked, a posterior bone block is indicated (Fig. 14-18). This consists of creating a bony prominence on the upper aspect of the posterior portion of the os calcis in a position to impinge on the posterior aspect of the tibia, preventing plantar flexion at the ankle. The source of this block may be the os calcis, tibial cortex, or the excised scaphoid

Should greater stability of the tarsus and ankle be desired, ankle fusion combined with tarsal arthrodesis (pan arthrodesis) may be carried out. Flail knee necessitates the use of a long leg brace or possibly fusion of the knee joint If permanent stiffening of the knee is to be considered,

essential in the salvage of skeletal function. As a stable base is of importance to any superstructure, a stable foot is essential to the best function of the legs, trunk, and even the upper extremities. Some degree of stability may be afforded by encasing the foot in shoes, splints or braces. This may suffice but more positive measures are usually indicated. When we realize the complexities of the structure and movement that are present in the foot and the instability that results from loss of muscle balance, we are more receptive to means of simplfying the mechanics of this structure, the foundation of the skeleton as it were.

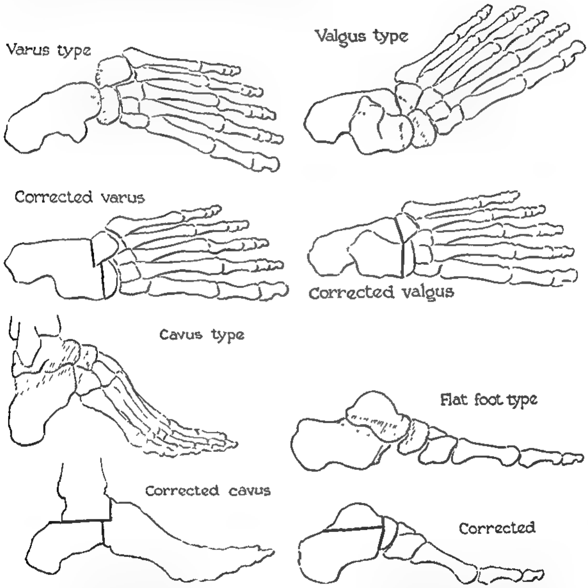


Fig. 14-15. Osteotomy and arthrodesis for correction of foot deformities Top left, varus deformity: using an osteotome, portions of the talus, calcaneus, navicular, and cuboid (stippled) are removed, along the lines indicated, thereby eliminating the talonavicular and calcaneocuboid joints. The opposing cancellous bone surfaces are then approximated, correcting the original varus. Top right, valgus deformity as in v[illegible] consisting of portions (stippled) of the same four bones, in s[illegible]ur-faces corrects the valgus Bottom left, cavus deform[illegible]d) of the talocalcaneal joints, as well as talonavicular [illegible]ity can be corrected Bottom right, flat foot deformity by appropriately altering the direction of the osteotome cut, a defect is produced (stippled portion removed) which when closed will elevate the longitudinal arch. (From White Am Acad Orthop Surg, Instructional Courses, 1944.)

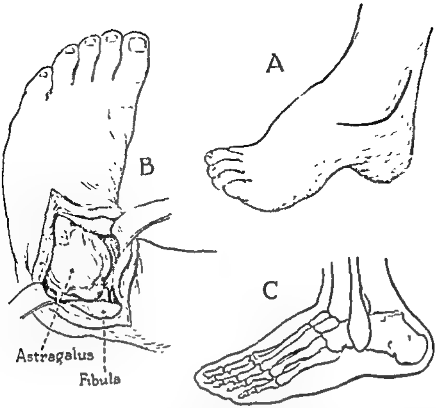


Fig. 14-17. Astragalectomy (Whitman) to stabilize foot. Excision of scaphoid as shown is done only in extreme calcaneus. The incision is started, A, just lateral to the head of the astragalus curving posteriorly as shown (Kocher incision). B, the astragalus is exposed subperiosteally, and, after mobilization, is removed from its bed. C, the foot is set back under the tibia as shown (After Campbell)

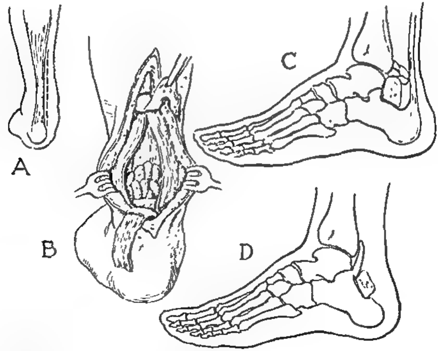


Fig 14-18. Campbell bone block for paralytic equinus (drop foot) A, line of incision; posterior surface of joint exposed by retraction or Z-plastic division of tendo achilles. B, operation completed, showing large block of bone with numerous small chips pyramided above. C, relation of block to subastragalar and ankle joints and the posterior surface of tibia D, bone block alone performed by reflection of bone forward and upward from superior surface of os calcis. (From Campbell, W C *Operative Orthopedics*, 2nd ed., 1949. Courtesy C V. Mosby Co)

the patient should be tested by the use of a long circular plaster splint, holding the knee in extension. This will reveal the advantages and disadvantages of a stiff leg and he can make his choice between the straight leg or flexible brace.

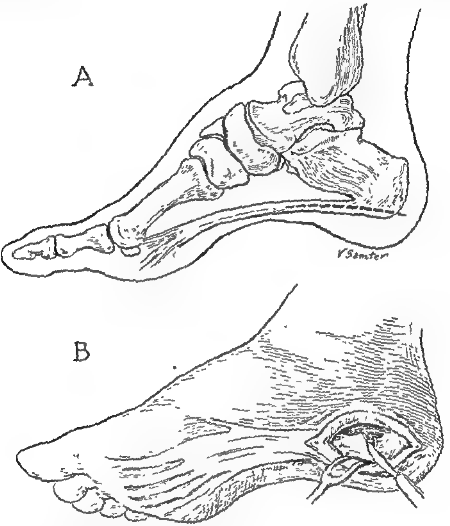


Fig 14-16. Plantar fasciotomy. A step in the correction of cavus deformity usually combined with some form of tarsal arthrodesis.

Flexibility at the hip is so desirable that ankylosis is rarely indicated. Should the instability be such as to permit subluxation, hip fusion is indicated.

In *flail shoulder* active scapular muscles are usually present. This motion can be transmitted to the humerus by means of bony ankylosis of the shoulder joint (Fig. 14-19). The joint is exposed by a saber cut incision and opened by excising the superior capsule. The articular cartilage is removed from the head of the humerus and from the glenoid cavity. The acromion process is exposed, bent downward to engage in a recess at the medial margin of the greater tuberosity of the humerus. Additional bone chips are placed across the joint and the arm placed in a shoulder spica cast, the humerus abducted 45 to 50 degrees and about 20 degrees anterior to the transverse body plane. This position will permit the arm to hang parallel to the trunk. All scapular movement is transmitted to the arm and a most useful range of movement attained.

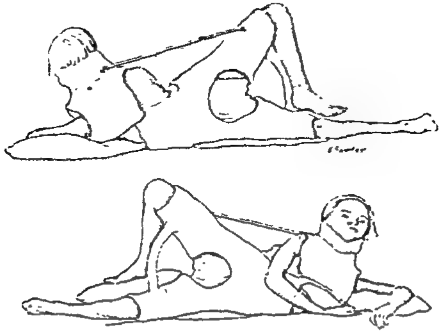


Fig 14-20. Hinged plaster jacket (Risser) for correction of scoliosis.

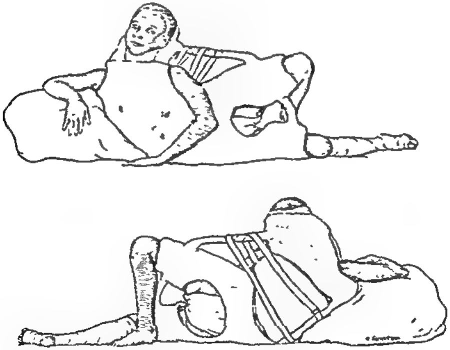


Fig 14-21 Hinged jacket stabilized and operative field uncovered for spine fusion operation and tibial graft to stabilize primary curve.

3. Realignment of Skeletal Structures. *Flexion deformity* of bony origin involving the knee joint is corrected by forceful stretching in plaster or by supracondylar osteotomy of the femur in more resistant cases. Knock knee and bowleg deformities are corrected in a similar manner (Fig. 14-23 B), or by inserting staples across the epiphysial plate on the convex side of the deformity, i.e., at distal femoral and/or proximal tibial epiphyses. External torsion of the tibia calls for transverse osteotomy of the tibia in its upper third with derotation of the lower fragment.

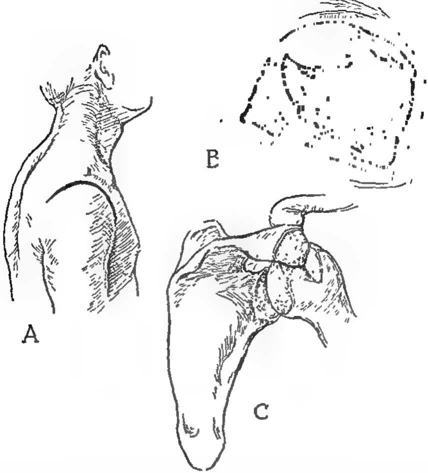


Fig 14-19 Arthrodesis of shoulder to transmit scapular movement to humerus in cases of flail shoulder joint A, skin incision B, the articular cartilage is removed from the head of the humerus and glenoid cavity C, the achromium is exposed and bent downward into a recess in the head of the humerus (After Campbell)

Scoliosis resulting from polio presents a most difficult problem, primarily because of the large number of vertebral segments involved as well as the great number of muscles acting on them. A lateral curve becomes a complex one in our effort to assume the upright position. It is still more complicated as a result of irregular growth of the vertebral elements Braces, plaster jackets, and corsets, are relatively ineffective in preventing progress of the deformity, for their corrective force is exerted against the rib cage and this gives way before much is expended upon the spine (Fig. 14-20) Exercises are of somewhat questionable value, for selective strengthening of the weakened muscle is difficult without improving the strength of the normal musculature which responds more readily. Exercise also increases flexibility and permits greater collapse. Both exercise and external support are used widely but their value is questioned in many quarters. Should the spinal curve show evidence of rapid increase, restoration of stability and simplification of the mechanics is indicated. This may be secured by forceful correction by traction and wedging casts and by consolidation of the deforming area by spine fusion operation (Fig. 14-21). The results of forceful correction and fusion operation, while falling far short of that which might be desired, are well worth while in the majority of cases.

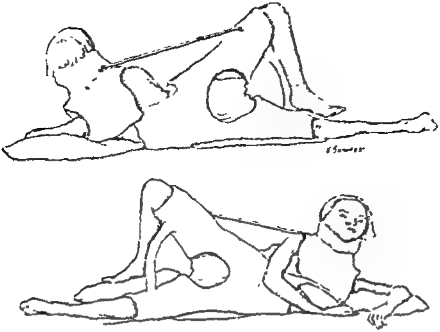
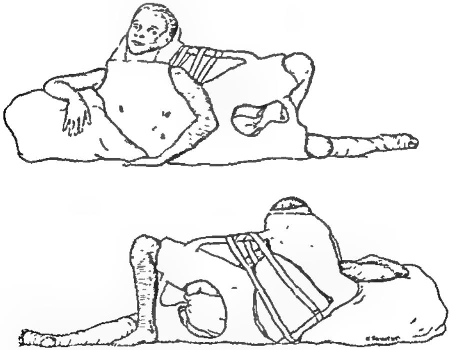


Fig 14-20 Hinged plaster jacket (Risser) for correction of scoliosis.



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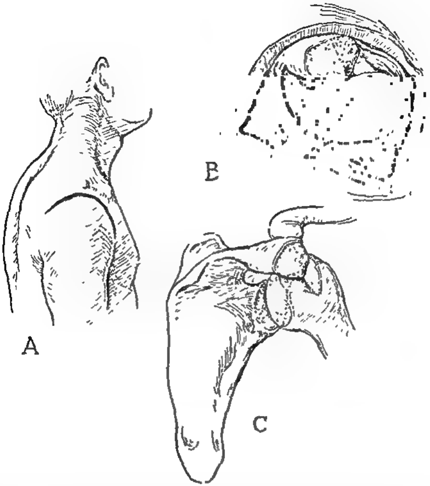

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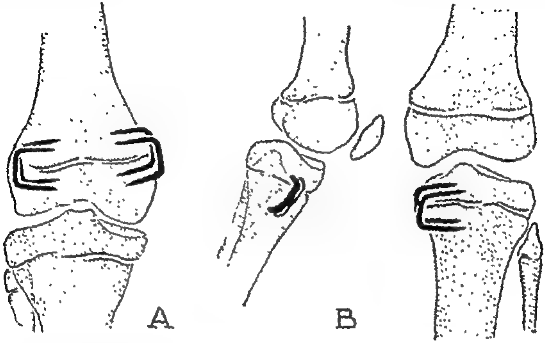

Fig. 14-23. An epiphysis may be stapled symmetrically to arrest growth (A), or asymmetrically to correct angulation (B) (From Campbell, W. C. *Operative Orthopedics*, 2nd ed., 1949. Courtesy C. V. Mosby Co.)

Leg lengthening has lost favor because of the hazards involved on the stretching of the soft parts, particularly the blood vessels and nerves.

The detail of surgical technics has been omitted because of the numerous procedures which are available. Reference to standard texts on orthopedic surgery will be most advantageous.

No deformity is of greater importance than that of flexion of the hip. This is due primarily to a contracture of the iliotibial band and the tensor fascia lata muscle. In mild cases transverse section of the iliotibial band is sufficient, but in the more severe deformities release of the tensor fascia lata from the crest of the ilium together with a radical resection of the anterior superior spine is necessary.

As a result of extensive paralysis of the muscles of the hip, particularly *the abductors, dislocation of the hip may occur. Stability following open* reduction is improved by the shelf operation of Campbell (Fig. 14-22).

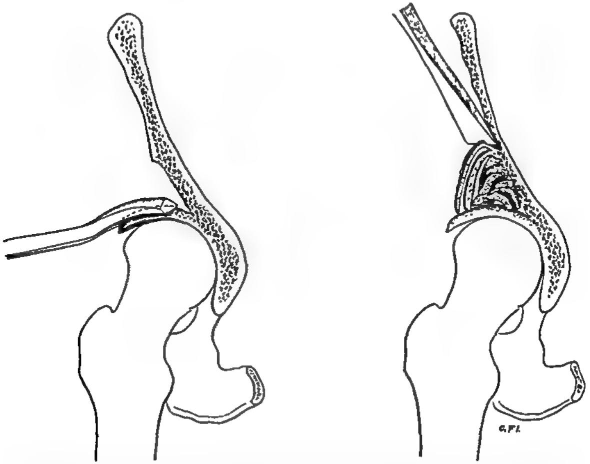

Fig. 14-22 Campbell's shelf construction for paralytic dislocation of the hip Left, the upper portion of the acetabulum is separated from the ilium as shown and carried down over the head of the femur. Right, the wedge-shaped space is filled with bone chips (From Campbell, W. C. *Operative Orthopedics*, 2nd ed, 1949 Courtesy C. V. Mosby Co.)

Unequal leg length resulting from muscular paralysis and disturbance of growth is corrected by epiphysial arrest of the more normally growing leg in children or by shortening of the femur in older patients. In epiphysial arrest, the epiphysial cartilage is excised permitting premature closure. A method that has largely replaced excision of the cartilage is the insertion of staples (Fig. 14-23) across the epiphysial plate (usually two medially and two laterally). This method has the advantage that removal of the staples will permit the resumption of growth, that is until the time of normal epiphysial closure. The time and extent of surgery should be carefully

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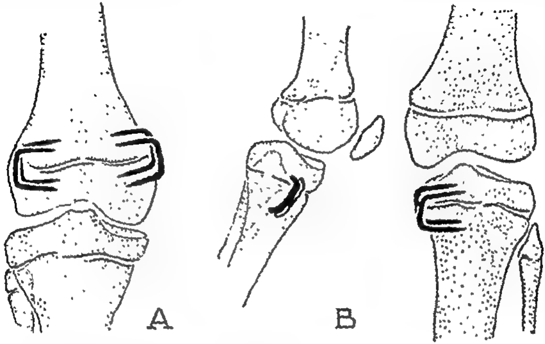

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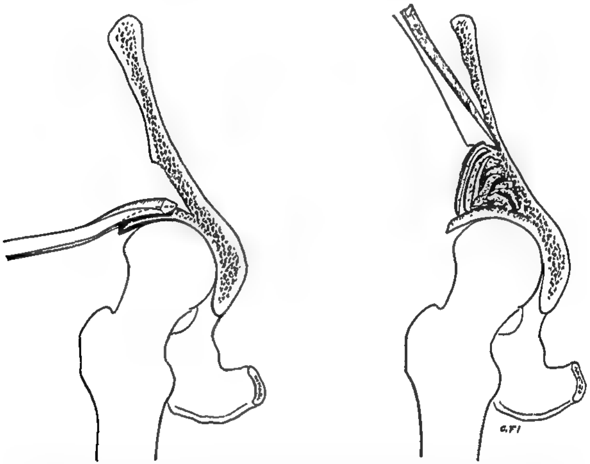

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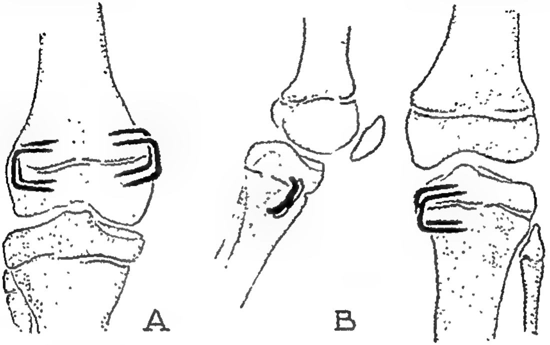

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15

THE AUTONOMIC NERVOUS SYSTEM

REGINALD H. SMITHWICK

After many centuries of thought, speculation, and study, pioneer anatomists, physiologists, and pharmacologists have gradually dispelled at least some of the mystery which has surrounded this portion of the human anatomy. Progress has been much more rapid since the turn of the century and particularly during the past 20 years. Pioneer surgeons have devised operations which are proving effective in alleviating various disorders for which there previously was no satisfactory form of therapy. As a result, the field of surgery is being extended beyond familiar bounds.

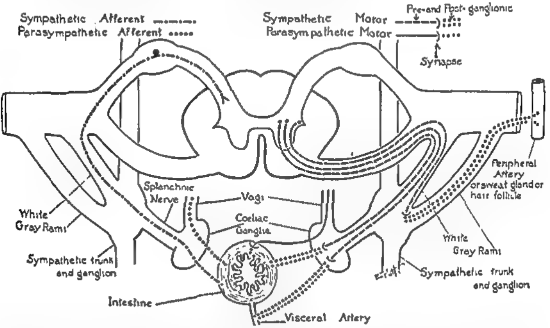

Fig. 15-1. Peripheral sympathetic and parasympathetic pathways. The peripheral portions of both sympathetic and parasympathetic pathways are shown on the right side of the figure. The synapses of the peripheral vasomotor fibers lie in the paravertebral ganglia, while those of visceral fibers lie in the prevertebral ganglia. Preganglionic sympathetic fibers synapse with several to many postganglionic fibers. By contrast, the parasympathetic synapses are located in or close to the structure in question and the relation between preganglionic and postganglionic fibers is generally 1 to 1. Afferent fibers are present in both the sympathetic and parasympathetic systems. They are indicated on the left side of the figure. Some complete reflex arcs, and others carry pain sensation. The latter are generally regarded as belonging to the somatic afferent system. Their cells lie in the dorsal root ganglia and the fibers traverse white communicating rami in order to reach the intercostal nerves and the posterior roots.

It is not within the scope of this chapter, which deals primarily with surgical technic, to review the vast amount of data which have accumulated in recent years. It seems proper, however, to emphasize that those who desire to take an active part in this growing field of surgery should familiarize themselves with the anatomy, physiology, and pharmacology

which are so intimately concerned with the performance of operations, the selection of cases for surgery, and the proper evaluation of results. It should also be understood that many points remain to be clarified, operations are still to be devised or perfected, and the final results of treatment of this sort for various disorders of the cardiovascular system and the gastrointestinal tract in particular are still to be evaluated.

The following abbreviated outline is given as an introduction to the discussion of surgical technic. It is felt that those who contemplate the performance of the various operations in current use should be familiar with the subject material covered. In Figure 15-1, the details of the peripheral autonomic pathways are indicated in a diagrammatic fashion.

I. Anatomy
    A General
        1. Sympathetic division
        2. Parasympathetic division
        3. Efferent and afferent fibers
        4. Central connections
    B. Peripheral pathways
        1. Sympathetic motor
            a Lateral horn cells
            b Anterior roots
            c Communicating rami, white and gray
            d. Peripheral nerves
            e Periarterial plexus
            f Synapses
            g Preganglionic and postganglionic pathways
        2 Parasympathetic motor
            a Preganglionic and postganglionic pathways
            b Synapses
        3 Autonomic afferents
            a. Cell bodies
            b. Peripheral and central connections
            c Reflex arcs—visceromotor
            d Visceral pain pathways

II Physiology
    A General functions of autonomic nervous systems
        1 Sympathetic division
        2 Parasympathetic division
    II Changes after section of nerves
        1 Paralysis
        2 Spontaneous hyperreactivity
        3 Sensitization phenomena
            a After preganglionic section
            b After postganglionic section
        4 Regeneration
    C Transmission of nerve impulses
        1 Acetylcholine
        2 Sympathin
        3 Cholinergic nerves
        4 Adrenergic nerves
        5 Sympathin (E), sympathin (I), chemical mediator (M), hypothetical substance (H)

III. Pharmacology
        1 Site of action of drugs—on cells rather than nerve terminals
        2 Sympathomimetic and parasympathomimetic drugs
        3 Chemical mediators of nerve impulses, sympathin and acetylcholine
        4 Blocking drugs
        5 Steps in transmission of nerve impulses—points at which blocking drugs may act

The brief bibliography which accompanies this chapter will help to clarify the points covered in the preceding outline as well as many other aspects of surgery of the autonomic system. Reference 15 is particularly useful because of the information which it contains concerning methods of study, the selection of patients for surgery of this sort, and the results.

The operations to be described can be performed by qualified surgeons with an extremely low operative mortality. For the most part, they should not be attempted without special training in this field of surgery.

CERVICAL SYMPATHECTOMIES

The most accessible part of the sympathetic chain is the cervical portion. It is not surprising that surgeons first directed their attention to this segment. Although a good many operations have been performed in an attempt to relieve a multitude of disorders, actually there are few clinical applications for cervical sympathectomy. Resection of the superior cervical ganglion has been performed to produce drooping of the upper eyelid.

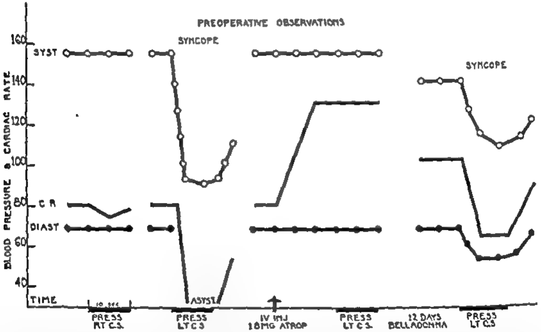

Fig. 15-2. Reflex responses to carotid sinus stimulation. The effect of pressure upon the sensitive carotid sinus is contrasted with the normal side. A noteworthy fall in blood pressure is associated with marked slowing of the heart rate. This was abolished by atropine administered intravenously and modified but not abolished by atropine by mouth. It can be abolished by novocain infiltration of the sinus and by surgical denervation. (After Ray and Stewart. Surgery, 11:915, 1942.)

This enables a patient to close his eye in the presence of paralysis of the facial nerve. Denervation of the carotid sinus by periarterial sympathectomy has been a useful procedure when other forms of therapy have failed. An abnormally sensitive carotid sinus is evidenced by episodes of syncope. This is the result of a reflex response to stimulation of pressor sensitive nerve endings. There are three types, which may occur singly or in combination: 1, asystole, or sudden slowing of pulse rate; 2, a fall in blood pressure; and 3, a change in cerebral circulation. Milder forms of the first and

second types may be controlled by atropine or ephedrine. X-ray treatment may also be effective. The physiologic responses in a case in which both asystole and hypotension followed sinus stimulation are illustrated in Figure 15-2. The inferior cervical, stellate, and upper thoracic ganglia may be removed through a cervical approach. Some surgeons prefer this to the posterior upper thoracic approach to this portion of the sympathetic trunk. In my experience, the latter is preferable in the great majority of cases in which one is interested in denervating the head and neck, heart, or upper extremity.

Resection of the Superior Cervical Sympathetic Ganglion. Good exposure for this operation may be obtained through a 5 cm. incision placed vertically along the anterior border of the sternomastoid muscle or through a transverse incision placed in a natural skin crease about an inch below the angle of the mandible so as to avoid the branch of the facial nerve to the lower lip (Fig. 15-3). The head is rotated to the opposite side and

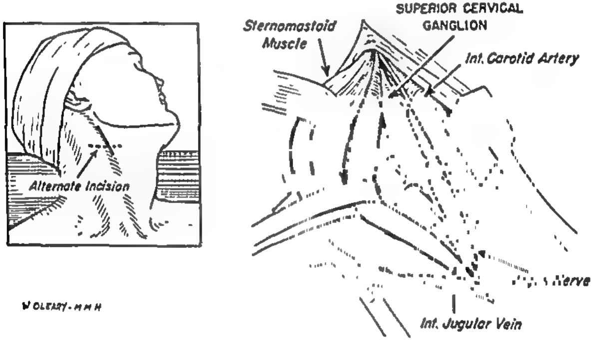

Fig. 15-3 Superior cervical ganglionectomy.

slightly extended. Local anesthesia is satisfactory, especially if the branches of the cervical plexus are also blocked as they emerge from the posterior border of the sternomastoid muscle. General anesthesia may of course be employed. The dissection is carried through the platysma and the superficial cervical fascia, exposing the anterior border of the sternomastoid muscle which is retracted laterally. The carotid sheath and its contents are then identified, and the internal jugular vein is retracted laterally. The vagus nerve and the internal carotid artery are readily identified. Palpation posteriorly along the anterolateral aspect of the upper cervical spine will identify the sympathetic trunk and the superior cervical ganglion running upward toward the base of the skull. The ganglion is usually large and fusiform in shape and is easily differentiated from the vagus, hypoglossal, and glossopharyngeal nerves which lie in the immediate vicinity. Communicating rami running from the ganglion to the upper cervical and to the

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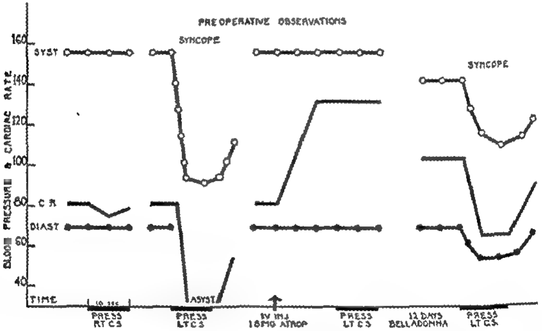

Fig. 15-2 Reflex responses to carotid sinus stimulation The effect of pressure upon the sensitive carotid sinus is contrasted with the normal side A noteworthy fall in blood pressure is associated with marked slowing of the heart rate This was abolished by atropine administered intravenously and modified but not abolished by atropine by mouth It can be abolished by novocain infiltration of the sinus and by surgical denervation (After Ray and Stewart Surgery, 11.915, 1942)

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It has been suggested by Telford that the upper extremity be denervated by a cervical approach. In my experience, the posterior approach is not *only easier* but affords greater opportunity to safeguard against regeneration. The principal indications for denervation of the upper extremity are

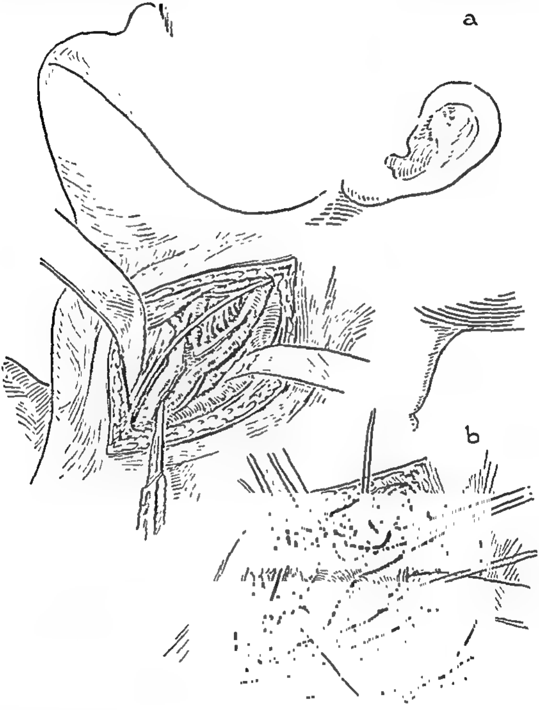

Fig 15-4 Denervation of carotid sinus The adventitia should be removed for 2 to 3 cm. above and below the bifurcation of the common carotid artery.

to inhibit vasoconstriction, and the treatment of severe types of hyperhidrosis and causalgia. Probably the only occasion when sympathectomy by the cervical approach is useful is when it is thought to be a necessary adjunct to excision of a cervical rib or resection of the scalenus anticus muscle.

other nerves mentioned are readily identified and divided. The ganglion, which is usually about 2 cm. in length and 0.5 cm. in width, is easily removed. The wound is closed in layers without drainage.

Denervation of the Carotid Sinus. Operation may be performed under local or general (intratracheal ether) anesthesia. It should be kept in mind that ether does not abolish carotid sinus reflexes. Barbiturates may increase its sensitivity and should be avoided. Intravenous atropine (1.8 mg.) eliminates the vagal type of response and should be used as a preliminary medication. It does not affect the other types. Infiltration of the region of the sinus with novocain is the best assurance against attacks during anesthesia or operation and should be used routinely (unilateral infiltration). The hypersensitivity is generally unilateral or much more marked on one side. Novocainization of both sinuses at once should be avoided because of the danger of respiratory difficulty due to bilateral recurrent nerve paralysis. Every precaution should be taken to guard against attacks during anesthesia or operation because they can be fatal.

The incision should be made along the anterior border of the sternomastoid muscle (Fig. 15-4). It is approximately 8 cm. in length and centered opposite the hyoid bone. The muscle is gently retracted posteriorly exposing the carotid sheath which is opened. The common carotid artery and its major branches are then readily identified. The adventitial coat is infiltrated with procaine 1 per cent for 2 or 3 cm. above and below the bifurcation if this has not already been done as a preliminary to operation. This not only will prevent attacks, but aids in the subsequent dissection. The internal jugular vein is mobilized over the full extent of the field, ligating one or more branches if necessary, and is retracted posteriorly. A Y incision is then made in the adventitia extending 2 cm. above the bifurcation on the external and internal branches and for a similar distance below on the common carotid artery (Fig. 15-4). The periarterial sheath is then readily separated from the entire circumference of the arteries. Small catheters can be placed about the vessels within the adventitia at the upper and lower limits of the field to facilitate posterior dissection. They also are useful for hemostatic purposes in case of injury to the arterial wall during the dissection. The superior thyroid artery can be ligated and divided if necessary. The greatest concentration of nerve fibers is along the adjacent surfaces of the external and internal carotid arteries, particularly the latter. This portion of the dissection is carried out last. When completed, the periarterial sheath has been removed from the common, external, and internal carotid arteries for at least 2 cm. above and below the bifurcation. The incision is closed in layers without drainage. Fine nonabsorbable suture material is used, preferably silk.

Cervicothoracic Sympathectomy by the Anterior Approach. The inferior cervical together with the upper two or three thoracic ganglia may be removed by a cervical approach. Although preferred by some for the relief of angina pectoris, this approach is not, in my opinion, as satisfactory as the posterior extrapleural. It is advisable to remove at least the upper four thoracic and the inferior cervical ganglia in cases of angina pectoris. An operation of this extent is performed with much greater facility by the latter approach.

and scapular vessels running across its lower portion. These may be divided, although occasionally they can be avoided. The omohyoid muscle is retracted upward. The phrenic nerve is then identified running from above downward, from the lateral to the medial border of the scalenus anticus muscle. The nerve is gently mobilized from the surrounding fascia so that it can be retracted medially with the jugular vein. Care is taken not to pinch or traumatize the nerve. The lateral and medial borders of the scalenus anticus muscle are identified and freed by careful dissection. It is then possible to pass a finger posteriorly from the lateral to the medial border of the muscle. The lower cords of the brachial plexus lie immediately lateral to the muscle and should be identified and avoided. One can then pass a right-angled clamp behind the muscle in the tunnel previously made by a finger. The clamp is opened and the muscle divided a few fibers at a time. This safeguards against injury to the plexus or phrenic nerve and permits easy ligation of one or two small muscular arteries of consequence. After division of the muscle, there is generally a layer of fascia immediately beneath, which is incised. The subclavian artery is then seen in the lower portion of the wound and can be gently retracted downward. One then can palpate the anterior edge of the first rib and the first intercostal nerve running upward to join the brachial plexus. Sibson's fascia running upward over the inner portion of the first rib is then divided, which permits gentle separation of the apical pleura from the upper thoracic cage and vertebral bodies. This is done by manual dissection and with experience can be accomplished easily and without injury to the pleura. The latter will occur occasionally even in most experienced hands, hence the desirability of intratracheal anesthesia. The inferior cervical ganglion and the upper portion of the sympathetic trunk can then be readily palpated on the anterolateral aspect of the vertebral column. Dissection of this structure is then carried out with the aid of nerve hooks and Hartmann forceps. It is difficult, as a rule, to get below the third thoracic ganglion. In cases of angina pectoris, one should ideally remove at least the inferior cervical and upper four thoracic ganglia. To denervate the upper extremity, one should decentralize the second, third, and fourth ganglia, divide and clip the trunk below the latter, clip the second, third, and fourth sets of rami and suture the distal end of the upper mobilized segment containing the second and third ganglia into the wound to minimize regeneration. Encasing the decentralized second and third ganglia in a silk cylinder is an additional safeguard against regeneration (Fig. 15-6). Some prefer to remove the inferior cervical and upper three or four thoracic ganglia to insure a complete denervation and to guard against regeneration. Also it is essential that the anterior roots of the second and third and preferably the fourth intercostal nerves be resected intraspinally whenever the upper extremity is to be denervated for vasospasm. This is the greatest single safeguard against regeneration. This can be done only through the posterior approach. The incision is closed in layers with interrupted nonabsorbable suture material. If an opening has been made in the pleura, a No. 24F catheter is inserted through it into the cavity and a second catheter placed in the extrapleural space. The latter is placed routinely whether the pleura is opened or not. After the wound is closed, the air is aspirated with a large asepto syringe,

Under intratracheal gas-oxygen-ether anesthesia with the patient in the position generally used for thyroidectomy, the head turned slightly to the opposite side, a transverse incision is made about a finger's breadth above and parallel to the clavicle. It should be 5 to 8 cm. in length, the anterior end lying over the middle of the sternomastoid muscle (Fig. 15-5). After

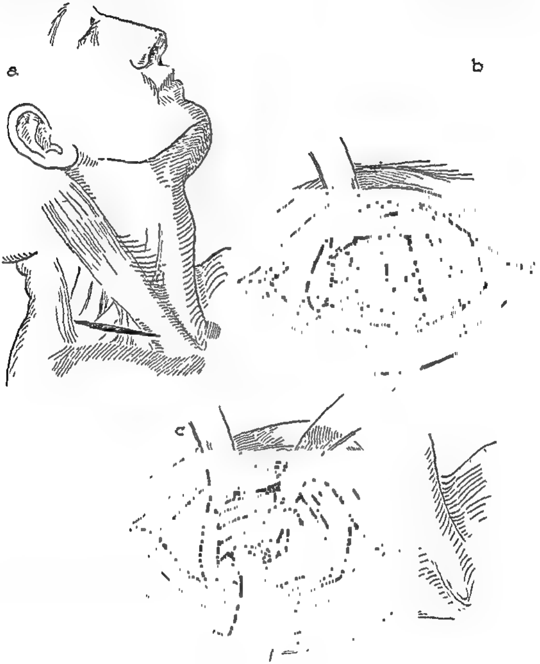

Fig. 15-5. Cervicothoracic sympathectomy. The stellate ganglion and the second and third thoracic ganglia can be removed by an anterior approach By and large, other technics are preferable for denervation of the heart or the upper extremity

application of skin towels, the dissection is carried down through the subcutaneous tissue and platysma. The external jugular vein is usually in the center of the wound and is doubly ligated and divided. The lateral head of the sternomastoid muscle is divided, while having in mind the fact that the internal jugular vein lies immediately beneath. At a slightly deeper plane, the scalenus anticus muscle is exposed, with the transverse cervical

and scapular vessels running across its lower portion. These may be divided, although occasionally they can be avoided. The omohyoid muscle is retracted upward. The phrenic nerve is then identified running from above downward, from the lateral to the medial border of the scalenus anticus muscle. The nerve is gently mobilized from the surrounding fascia so that it can be retracted medially with the jugular vein. Care is taken not to pinch or traumatize the nerve. The lateral and medial borders of the scalenus anticus muscle are identified and freed by careful dissection. It is then possible to pass a finger posteriorly from the lateral to the medial border of the muscle. The lower cords of the brachial plexus lie immediately lateral to the muscle and should be identified and avoided. One can then pass a right-angled clamp behind the muscle in the tunnel previously made by a finger. The clamp is opened and the muscle divided a few fibers at a time. This safeguards against injury to the plexus or phrenic nerve and permits easy ligation of one or two small muscular arteries of consequence. After division of the muscle, there is generally a layer of fascia immediately beneath, which is incised. The subclavian artery is then seen in the lower portion of the wound and can be gently retracted downward. One then can palpate the anterior edge of the first rib and the first intercostal nerve running upward to join the brachial plexus. Sibson's fascia running upward over the inner portion of the first rib is then divided, which permits gentle separation of the apical pleura from the upper thoracic cage and vertebral bodies. This is done by manual dissection and with experience can be accomplished easily and without injury to the pleura. The latter will occur occasionally even in most experienced hands, hence the desirability of intratracheal anesthesia. The inferior cervical ganglion and the upper portion of the sympathetic trunk can then be readily palpated on the anterolateral aspect of the vertebral column. Dissection of this structure is then carried out with the aid of nerve hooks and Hartmann forceps. It is difficult, as a rule, to get below the third thoracic ganglion. In cases of angina pectoris, one should ideally remove at least the inferior cervical and upper four thoracic ganglia. To denervate the upper extremity, one should decentralize the second, third, and fourth ganglia, divide and clip the trunk below the latter, clip the second, third, and fourth sets of rami and suture the distal end of the upper mobilized segment containing the second and third ganglia into the wound to minimize regeneration. Encasing the decentralized second and third ganglia in a silk cylinder is an additional safeguard against regeneration (Fig. 15-6). Some prefer to remove the inferior cervical and upper three or four thoracic ganglia to insure a complete denervation and to guard against regeneration. Also it is essential that the anterior roots of the second and third and preferably the fourth intercostal nerves be resected intraspinally whenever the upper extremity is to be denervated for vasospasm. This is the greatest single safeguard against regeneration. This can be done only through the posterior approach. The incision is closed in layers with interrupted nonabsorbable suture material. If an opening has been made in the pleura, a No. 24F catheter is inserted through it into the cavity and a second catheter placed in the extrapleural space. The latter is placed routinely whether the pleura is opened or not. After the wound is closed, the air is aspirated with a large asepto syringe,

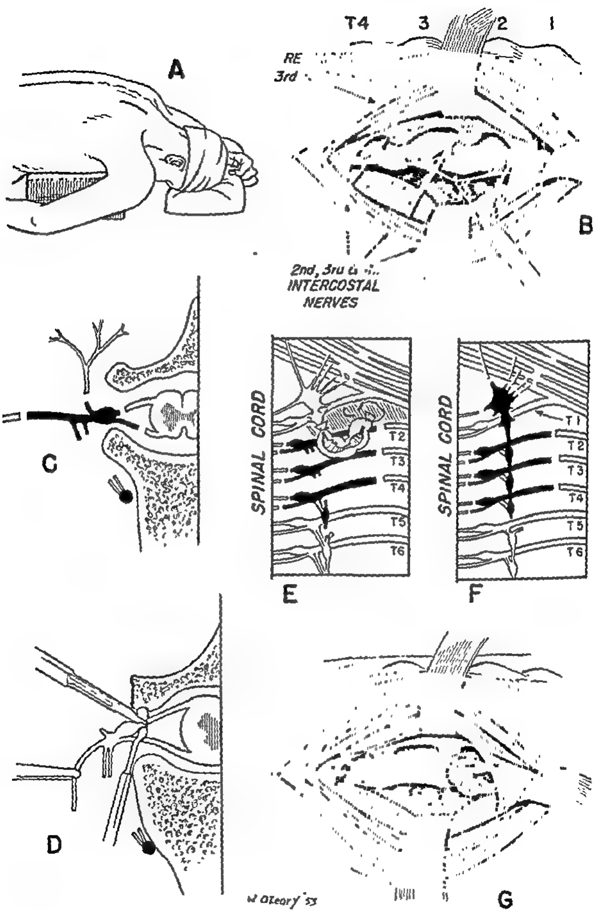

Fig. 15-8 Dorsal and upper thoracic sympathectomy.

while gentle positive pressure is applied. The catheters are then withdrawn. It is inadvisable to attempt to suture openings in the pleura.

THORACIC AND THORACOLUMBAR SYMPATHECTOMIES

Posterior Extrapleural and Retroperitoneal Approaches. The thoracic and thoracolumbar portions of the sympathetic nervous system are of great importance. When appropriate segments are removed, the course of a variety of disorders involving the head, upper extremity, heart, and the abdominal viscera can be favorably modified. This area can be readily exposed by a posterior extrapleural and retroperitoneal approach. The patient is placed in the prone position. A firm hair mattress of appropriate size is placed beneath the upper sternum and a second supports the pelvis in such fashion that the abdomen is free of pressure. The position is exactly as shown in Figures 15-6A, 8A and 9A. The only exception is that in the case of upper thoracic sympathectomies the arm on the side to be operated upon or both arms in the case of a bilateral procedure should be at the patient's side so that the medial border of the scapula will swing laterally away from the paravertebral area. Also, a small pillow should be placed on top of the hair mattress directly beneath the upper two thirds of the sternum. A side tilting table and intratracheal anesthesia should be used.

UPPER THORACIC SYMPATHECTOMIES

Denervation of the Blood Vessels of the Upper Extremity. The surgical technic employed varies with the purpose of the operation. If one wishes to denervate the blood vessels of the upper extremity the procedure to be described next is recommended.

A vertical paravertebral incision about 7 cm. long is made and centered opposite the space between the second and third thoracic spinous processes. It is placed 4 cm. lateral to the midline (Fig. 15-6). After careful application of skin towels the incision is carried down through the deep fascia to the trapezius muscle. The fibers of the latter are incised vertically for several centimeters in the center of the incision. This exposes the underlying rhomboid, which is divided obliquely in the direction of its fibers. A finger can then be passed upward and downward beneath this muscle and the ribs palpated and counted accurately. If the incision is properly placed, the oblique split in the rhomboid will lie directly over the third rib. The first rib is sometimes a little difficult to feel. The second is very prominent and beginners are apt to count it as the first. If one feels carefully over this prominent rib the first will be identified with certainty. An x-ray is essential to exclude a cervical rib. After identification of the third rib, the overlying longissimus cervicis muscle is split vertically, the intercostal muscles are separated by sharp (scissors) dissection from the upper and lower borders of the rib and the inner 4 cm. are removed including the periosteum. If one divides the external intercostal muscle and the fascia between it and the internal muscle layer close to the rib one can then pass a finger around the rib, outside of the periosteum and between it and the pleura and the intercostal nerve artery and vein, with minimal

danger of injuring these structures. This technic is preferable to subperiosteal resections in this region. The tip of the transverse process can be removed with rongeurs, and the underlying remnant of rib is removed for a centimeter or so. The pleura is then gently separated with a finger to the midline of the vertebral column, to a point above the first and below the fourth rib, and laterally to the resected rib end. The fourth rib is then resected in a similar manner. The third intercostal bundle with the exception of the nerve is then removed. The third intercostal nerve is readily visible in the middle portion of the wound, the second being concealed beneath the second rib in the upper portion of the wound, while the fourth intercostal nerve is seen crossing the lower portion of the wound (Fig. 15-6B). The following maneuver is then carried out and is depicted diagrammatically (Fig. 15-6C, D). It is called intraspinal root section and is designed to prevent regeneration from the second, third, and fourth thoracic segments. The third intercostal nerve is picked up with a hook, being certain that the intercostal artery and vein are not included. The nerve is divided at the lateral extent of the incision. It is followed to the intervertebral foramen, dividing the communicating rami running from the anterior aspect of the nerve to the corresponding thoracic ganglion. A dental spatula can then be slipped about the dorsal branch of the intercostal nerve and this is divided. This branch runs vertically and posteriorly between the transverse processes and is given off just lateral to the posterior root ganglion. The latter then comes into view and the spatula is inserted between the anterior and posterior roots at the proximal end of the ganglion. The posterior root is divided with a knife against the spatula blade, leaving the anterior root intact. The arachnoid is then pushed medially with the spatula and separated from the anterior root so that the latter is white and glistening and is free in the foramen. A small spinal fluid leak results. The root is then divided with scissors, so that the lateral centimeter is removed. The proximal end retracts within the canal and after the meninges heal, theoretically it should not regenerate. The second and fourth intercostal nerves are treated in a similar fashion. The sympathetic trunk is then palpated. It lies on the anterolateral aspect of the vertebral column exactly where the head of the rib contacts the vertebral body. It is hooked between the second and third ganglia and is mobilized from below the fourth ganglion to above the second. The trunk is clipped and divided just distal to the fourth ganglion and the decentralized second and third ganglia are encased in a silk cylinder. The distal end is sutured to the intercostal muscle in the upper portion of the incision. The fourth ganglion is discarded (Fig. 15-6E, G).

An alternate technic is to perform the root sections as described above but to mobilize the sympathetic trunk to include the first thoracic and preferably the inferior cervical ganglion as well. Instead of encasing the upper portion of the trunk in a silk cylinder, the sympathetic chain is removed from above the stellate ganglion to below the fourth (Fig. 15-6F).

Theoretically this alternate procedure would eliminate any vasomotor fibers which may leave the cord by way of the first intercostal nerve and which pass through the first thoracic or inferior cervical ganglia to reach the brachial plexus. Such pathways are present occasionally. On the other hand, it is known that vasomotor pathways do exist which have their

synapses in small ganglia which lie in close approximation to the intercostal nerves (Skoog's ganglia) and do not reach the brachial plexus by way of the paravertebral ganglia (Fig. 15-7). Consequently, there may still be slight residual vasomotor control after dorsal sympathectomy performed by either of the technics described since the first thoracic nerve cannot be resected because of the motor and sensory defects which would result.

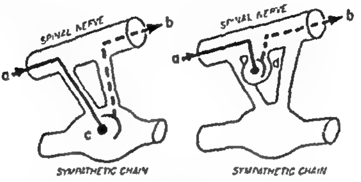

Fig 15-7. Demonstrating the manner in which sympathetic motor impulses can reach the periphery even after the paravertebral sympathetic trunk and ganglia have been removed. (After White et al *The Autonomic Nervous System*, 1952. Courtesy The Macmillan Co.)

There probably will be no significant difference in the late results of either technic. The first is certainly preferable for unilateral procedures since a Horner's sign is disfiguring especially in young females. Both technics are designed to result in as complete a denervation as possible and to guard against regeneration. *The most essential feature of each is the intraspinal section of the anterior roots of the second, third, and fourth intercostal nerves.*

The incision is closed carefully in layers with interrupted silk sutures, after a catheter (No. 24F) has been placed in the extrapleural space. After the wound is closed, any residual air is aspirated and the catheter removed. If the pleura is opened, no attempt is made to close it. Instead, a second catheter is inserted within the pleural space and aspirated after the wound is closed while gentle positive pressure is used to expand the lung. The catheter is then withdrawn.

Denervation of the Head and Upper Extremity for Various Disorders. The preceding discussion emphasized the need for using a detailed technic if the vasomotor control of the upper quadrant of the body is to be interrupted. In the last few years, dorsal sympathectomies have been performed to relieve Ménière's disease and in certain cases of tinnitus and deafness. The early results are promising in carefully selected cases. It is presumed that the beneficial effects result from denervating the blood supply of the ear, and for that reason the technic just described is recommended. The same is true if the upper extremity is to be denervated for causalgia or post-traumatic painful neurovascular syndromes since in both instances relief is probably due to interrupting the vasomotor fibers to the extremity. On the other hand, if one wishes to denervate the upper portion of the body for severe hyperhidrosis, it is necessary only to remove the second or

danger of injuring these structures. This technic is preferable to subperiosteal resections in this region. The tip of the transverse process can be removed with rongeurs, and the underlying remnant of rib is removed for a centimeter or so. The pleura is then gently separated with a finger to the midline of the vertebral column, to a point above the first and below the fourth rib, and laterally to the resected rib end. The fourth rib is then resected in a similar manner. The third intercostal bundle with the exception of the nerve is then removed. The third intercostal nerve is readily visible in the middle portion of the wound, the second being concealed beneath the second rib in the upper portion of the wound, while the fourth intercostal nerve is seen crossing the lower portion of the wound (Fig. 15-6B). The following maneuver is then carried out and is depicted diagrammatically (Fig. 15-6C, D). It is called intraspinal root section and is designed to prevent regeneration from the second, third, and fourth thoracic segments. The third intercostal nerve is picked up with a hook, being certain that the intercostal artery and vein are not included. The nerve is divided at the lateral extent of the incision. It is followed to the intervertebral foramen, dividing the communicating rami running from the anterior aspect of the nerve to the corresponding thoracic ganglion. A dental spatula can then be slipped about the dorsal branch of the intercostal nerve and this is divided. This branch runs vertically and posteriorly between the transverse processes and is given off just lateral to the posterior root ganglion. The latter then comes into view and the spatula is inserted between the anterior and posterior roots at the proximal end of the ganglion. The posterior root is divided with a knife against the spatula blade, leaving the anterior root intact. The arachnoid is then pushed medially with the spatula and separated from the anterior root so that the latter is white and glistening and is free in the foramen. A small spinal fluid leak results. The root is then divided with scissors, so that the lateral centimeter is removed. The proximal end retracts within the canal and after the meninges heal, theoretically it should not regenerate. The second and fourth intercostal nerves are treated in a similar fashion. The sympathetic trunk is then palpated. It lies on the anterolateral aspect of the vertebral column exactly where the head of the rib contacts the vertebral body. It is hooked between the second and third ganglia and is mobilized from below the fourth ganglion to above the second. The trunk is clipped and divided just distal to the fourth ganglion and the decentralized second and third ganglia are encased in a silk cylinder. The distal end is sutured to the intercostal muscle in the upper portion of the incision. The fourth ganglion is discarded (Fig. 15-6E, G).

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Theoretically this alternate procedure would eliminate any vasomotor fibers which may leave the cord by way of the first intercostal nerve and which pass through the first thoracic or inferior cervical ganglia to reach the brachial plexus. Such pathways are present occasionally. On the other hand, it is known that vasomotor pathways do exist which have their

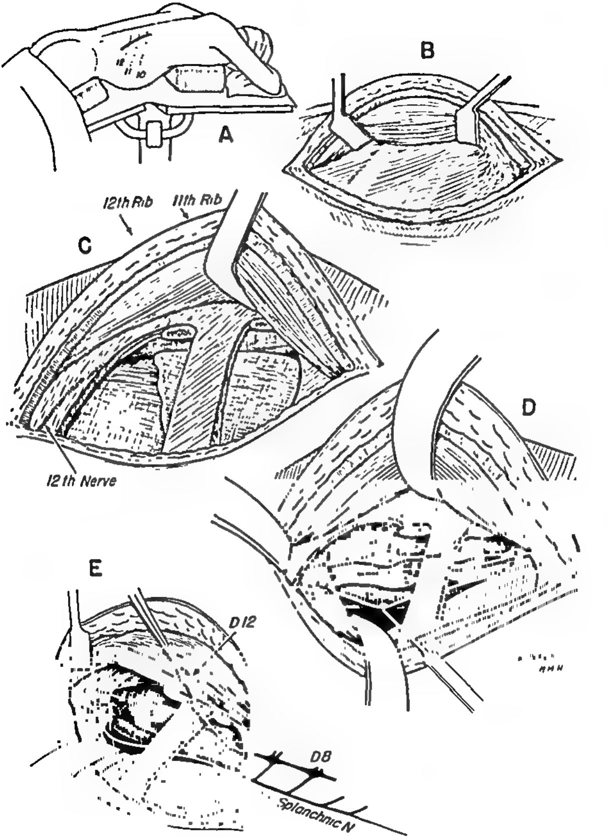

Fig. 15-8 Smithwick modification of Peet technic for supradiaphragmatic splanchnicectomy.

preferably the second and third thoracic ganglia. This can usually be done with facility after resecting the third rib only. The general exposure is the same as shown in Figure 15-6. Regeneration of sudomotor fibers after simple ganglionectomy has never been a problem. The results of dorsal sympathectomy for hyperhidrosis are excellent.

Denervation of the Heart. A posterior extrapleural approach may be used to denervate the heart. If the problem is cardiac pain, it is advisable to remove the inferior cervical and upper four or five thoracic ganglia. To interrupt the motor fibers, the second to the fifth thoracic ganglia inclusive should be resected bilaterally. This procedure is indicated to control refractory forms of tachycardia. The results are excellent. The incision and position (Fig. 15-6) are the same as used to denervate the upper extremity. The inner 4 or 5 cm. of the third and fourth ribs are resected. The sympathetic trunk is then removed from the inferior cervical to the fifth thoracic ganglion inclusive. The trunk is clipped proximally and distally and all rami are treated in a similar fashion. It is not necessary to resect the intercostal nerves as regeneration is rarely a problem after division of viscerosensory or motor nerves to the heart. The results of surgical denervation of the heart for relief of angina pectoris are good and far superior to those following paravertebral alcohol injection. It is the procedure of choice in good risk patients. If the pain is bilateral it will be necessary to denervate the other side either at the same time or at a second stage, usually about 10 days later.

Supradiaphragmatic Splanchnicectomy. The upper portion of the visceral vascular bed can be denervated by the posterior extrapleural approach. This operation has been used extensively in some clinics for the relief of hypertension and was first described by Peet. He has also discussed the late results. A more extensive procedure has been found to be preferable in most cases in my experience (see Lumbodorsal Splanchnicectomy). Partial splanchnicectomy is helpful in the relief of visceral pain arising in the upper small bowel, pancreas, or biliary tract. Lumbodorsal splanchnicectomy is a more effective procedure in the great majority of hypertensive patients. It also permits exploration of the subdiaphragmatic space, particularly the adrenal and kidney which, in my opinion, should be part of any operation in these cases. Supradiaphragmatic splanchnicectomy for hypertensive disease is utilized principally in older age or poor risk patients or as a first stage of a total thoracic sympathectomy and splanchnicectomy when one is not quite certain that the heart should be denervated because of questionable angina or borderline tachycardia. It is performed as follows. A paravertebral incision is made, centered over the eleventh rib (Fig. 15-8). The incision is placed 4 cm. lateral to the midline and should be 8 cm. long. The lateral edge of the sacrospinalis muscle is identified after incising the deep fascia and any underlying fibers of the latissimus dorsi muscle which may be present as well as the fascia beneath this muscle over the sacrospinalis group. The latter is reflected medially and the inner 5 cm. of the eleventh and all of the twelfth ribs are removed. The pleura is readily reflected digitally from the vertebral column and lower ribs. The sympathetic trunk is identified and is resected from the eighth to the twelfth thoracic ganglia inclusive. The trunk is clipped proximally and distally as

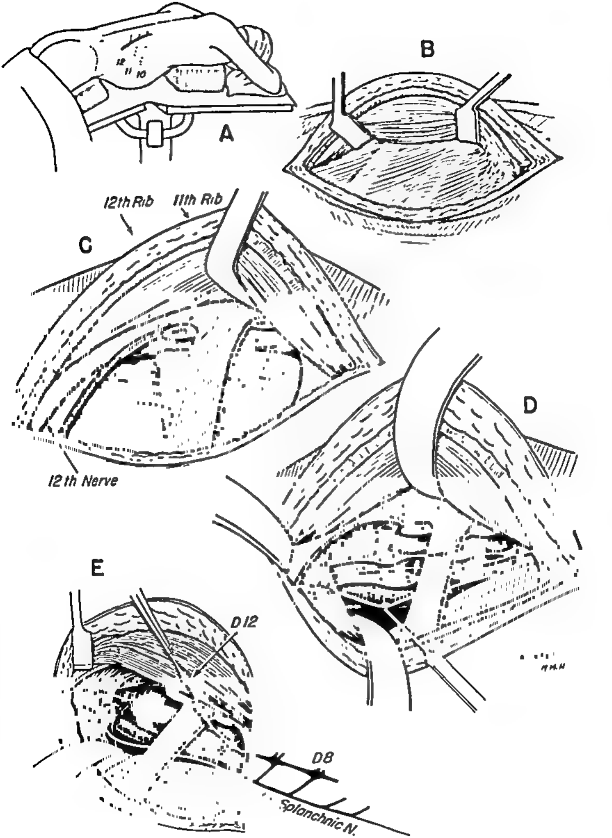

Fig 15-8 Smithwick modification of Peet technic for supradiaphragmatic splanchnicectomy.

well as all communicating rami. The great splanchnic nerve is readily seen, hooked, clipped, and divided just above the celiac ganglion. The trunk can then be dissected upward. This is best done digitally. A long extent of this should be removed, 15 cm. or more, clipping the upper end, or in case it is a fine filament it can be avulsed. The incision is closed carefully in layers with interrupted nonabsorbable sutures, the same precautions being observed to aspirate all residual air by means of catheters as previously described. In hypertensive patients the operation must be bilateral. As has been previously stated, a more extensive exposure and excision is preferable in most hypertensive patients (see Lumbodorsal Splanchnicectomy). These operations are usually performed in one stage both in hypertensive patients and in visceral pain problems. The average postoperative hospital stay is two weeks.

Lumbodorsal (Thoracolumbar) Splanchnicectomy. This technic for denervation of the splanchnic bed is one that I have used more than any other in the treatment of hypertension and hypertensive cardiovascular disease. It was first described in 1940 and was the outcome of multiple stage operations. Certain patients in whom previous lesser procedures had been ineffective in modifying the hypertension were subjected to further surgery. In some, lumbar chains were removed in two stages or a bilateral subdiaphragmatic splanchnicectomy was performed after an unsuccessful supradiaphragmatic maneuver. In others, a supradiaphragmatic splanchnicectomy was added to a previous subdiaphragmatic procedure. In one case, an unsuccessful laminectomy with extensive anterior root section was converted into an excellent result by a secondary lumbodorsal splanchnicectomy. Thus it was shown that failures could be due to inadequate denervation. In other cases, recurrent hypertension following a lesser maneuver was again modified by converting the original operation into a lumbodorsal splanchnicectomy. It was therefore felt that the statistical chances of a worth-while result would be increased in unselected cases by this more extensive type of splanchnicectomy. As a consequence, it was hoped that eventually our ability to select cases with accuracy would be improved since other factors affecting the reversibility of the hypertensive state could be better evaluated if failures were not so likely to be due to inadequate denervation. It seemed also that such a procedure would be an additional safeguard against regeneration. This operation is in effect a combination of the supradiaphragmatic and subdiaphragmatic technics. The operative mortality has been low. It is performed bilaterally in one stage with rare exceptions. The procedure can be performed in two stages if circumstances during operation make this advisable. In this case, the second stage is performed 10 days later. Postoperative complications have been few, the most frequent being hemothorax, usually extrapleural, sufficient to require aspiration in about 5 per cent of the cases. The average hospital stay is three weeks after the one stage procedure and four weeks after the two stage operation.

The technic of lumbodorsal splanchnicectomy is as follows: the patient is placed in the prone position, the chest and pelvis being supported so that there is no pressure upon the abdomen (Fig. 15-9). The table is broken slightly to flatten the lumbar spine. Intratracheal anesthesia should

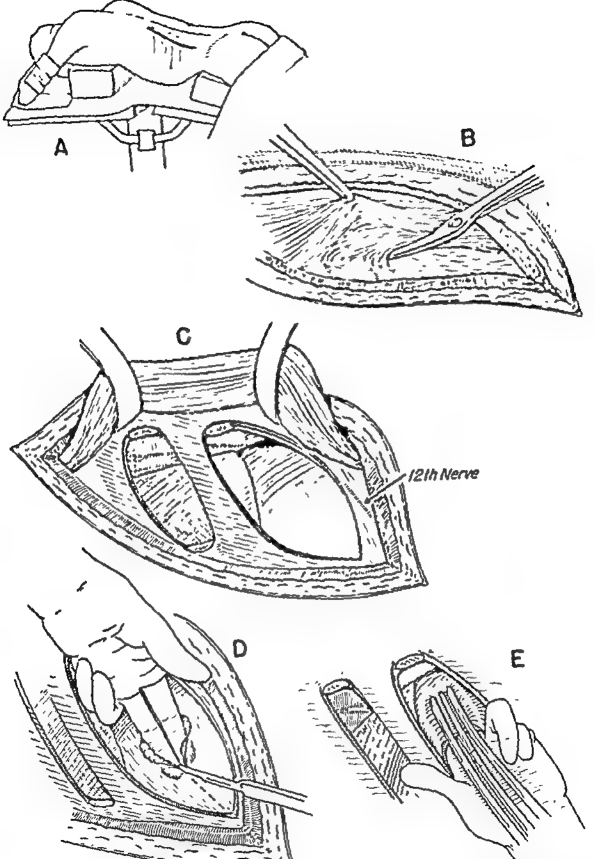

Fig 15-9 Lumbodorsal splanch- ... ie bed can be thoroughly dener-
vated by lumbodorsal ... he position of the patient is im-
portant The chest and ... so that there is no pressure upon
the abdomen Paraverte ... are made and portions of the eleventh and all of the
twelfth ribs are resected.

be used. A paravertebral incision is made. The upper portion is placed 3 to 4 cm. from the midline over the lateral third of the sacrospinalis muscle group and overlying the inner portion of the ninth rib. It runs downward and slightly outward to cross the twelfth rib at the lateral edge of the sacrospinalis muscle and then continues downward with a slight inward curve to the iliac crest. The dissection is carried down through the deep fascia, through fibers of the latissimus dorsi muscle, opening the underlying sacrospinalis sheath from the top of the incision to below the twelfth rib Below this point the deep dissection is carried downward and slightly laterally to the lumbodorsal fascia, incising the deep fascia and a few filaments of the oblique abdominal muscles. The lateral edge of the sacrospinalis muscle is elevated exposing the underlying eleventh and twelfth ribs. A very liberal portion of the former, about 8 cm., should be removed lateral to the transverse process. All of the twelfth rib is resected. The eleventh intercostal bundle between is left intact. The twelfth intercostal vessels may be resected if in the way in the lower portion of the field, being careful not to injure the twelfth nerve which lies in a deeper plane under the lateral edge of the quadratus lumborum muscle. The pleura is separated from the thoracic cage with gentle finger dissection. This dissection is best accomplished by working gently inward to the plane of the great splanchnic nerve, then upward to above the inner end of the eighth rib. The finger is then swept gently laterally and from above downward to the lateral end of the resected eleventh rib. An incision is then made through the renal fascia just lateral to the diaphragm. The perirenal fat protrudes through this opening.

The fascia is further divided laterally and downward, following which the dissection is carried medially and downward beneath this fascial layer and the diaphragm and over the psoas muscle to the lumbar spine. The diaphragm is then divided together with the adherent underlying fascia between clamps. There are always vessels of consequence in the diaphragm which require ligation. The ascending lumbar and at times the azygos or hemiazygos veins pass through the same hiatus as the trunk. Care must be taken to visualize these so that they are not inadvertently injured as serious bleeding may result.

After the diaphragm has been divided, the exposure is complete (Fig. 15-10). The table is then tilted laterally about 30 degrees away from the operator. The kidney and its pedicle are inspected and the adrenal gland as well It is best to detect the presence of a possible adrenal tumor at this point. These are found in 3 to 4 per cent of cases, although only an occasional tumor appears to play an active role in maintaining elevated blood pressure. If a tumor is present it is removed. Unless a dramatic fall in blood pressure ensues immediately, it is best to proceed with splanchnicectomy. Renal abnormalities can be detected and handled with facility. The lumbar portion of the trunk is readily palpated and cleared manually of overlying fat and fascia. A narrow Deaver retractor is inserted to displace the psoas muscle slightly. Moist gauze is placed over the kidney and its pedicle and these are gently displaced downward with a lighted brain spoon or ribbon retractor.

The sympathetic trunk is then best elevated with a long Crile type

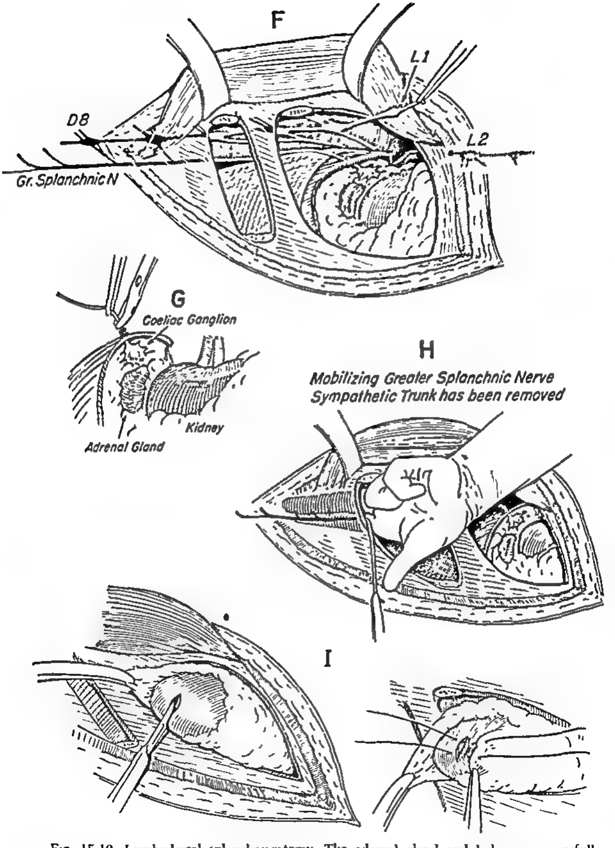

Fig. 15-10 Lumbodorsal splanchnicectomy The adrenal gland and kidney are carefully inspected If an adrenal tumor is present it should be detected and removed at this point. The sympathetic trunk is removed from D8 to L1 inclusive and the great splanchnic nerve is removed from the celiac ganglion to the midthoracic level. A kidney biopsy is taken

nerve hook just below the eleventh ganglion. It is followed downward into the lumbar region. The trunk between the twelfth thoracic and first lumbar ganglia is always very flimsy. The twelfth thoracic ganglion and its rami may lie entirely beneath the diaphragm, particularly in patients having a short twelfth rib. There are numerous variations in the anatomy of this region. It is felt that the standard procedure should be the removal of the sympathetic trunk from the eighth thoracic to the first lumbar ganglia inclusive. The second and the third lumbar ganglia are rarely removed, unless the postural blood pressure reflex is unusually active as evidenced by an abnormal rise of diastolic pressure not associated with an abnormal increase in heart rate when the patient shifts from the horizontal to the upright position. Ejaculation is usually not affected after removal of both first lumbar ganglia. If, in addition, one second lumbar ganglion is removed, about half of the patients may not ejaculate. Orgasm is rarely affected. Impotence is uncommon and is usually transient if only the first lumbar ganglia are removed. If both second lumbar ganglia are removed, loss of ejaculation is the almost invariable consequence. If male patients insist that ejaculation be preserved at any cost, it is best to stop the downward dissection just above the first lumbar ganglion on one side. We do this occasionally, provided that the patient understands that the operation may be less effective. The degree of postural hypotension in the acutely denervated state varies according to the extent of the removal of the lumbar ganglia, being absent or inconsequential if they are not removed, moderate if both first lumbar ganglia are excised, and marked if the second lumbar ganglia are removed, and profound if the third are removed on both sides. The time required for adjustment to the upright position after operation varies accordingly. During this period a snug abdominal binder and leg bandages or elastic stockings from instep to knee are used. If only the first lumbar ganglia are removed the great majority of patients are not severely handicapped in the acutely denervated state and are usually able to return to work about two months after leaving the hospital. This period of convalescence may be considerably prolonged if the second or third lumbar ganglia are removed.

After completion of this lumbar portion of the operation, the lower thoracic chain is removed from below upward to include the eighth ganglion in all instances (Fig. 15-10). All rami as well as the trunk proximally and distally are carefully ligated with silk or tantalum clips. It is felt that the portion of the dissection which lies above the ninth ganglion adds nothing to the completeness of the splanchnic denervation but may be an additional safeguard against regeneration. In removing the sympathetic trunk, all of the lesser, least and upper lumbar splanchnic nerves which have their origin in the excised main trunk are necessarily included. A diagrammatic representation of the anatomic pathways to the splanchnic bed is shown (Fig. 15-11).

The great splanchnic nerve is then identified, elevated upon a hook, crushed, doubly clipped and divided just above the celiac ganglion. It is then freed upward by manual dissection (Fig. 15-10) in order to avoid injuring the azygos or hemiazygos vein or the thoracic duct with which it is intimately associated. If it terminates in the sympathetic trunk at the

seventh ganglion, as it occasionally does, it is removed up to this point. More commonly, a fine strand runs upward, and this is best avulsed with a long right-angled clamp. Modifications of this technic which entail the resection of the tenth rib in order to remove additional ganglia are not regarded as worth while. It is felt that if further surgery is indicated, the remaining portion of the upper thoracic trunk should be removed at a later

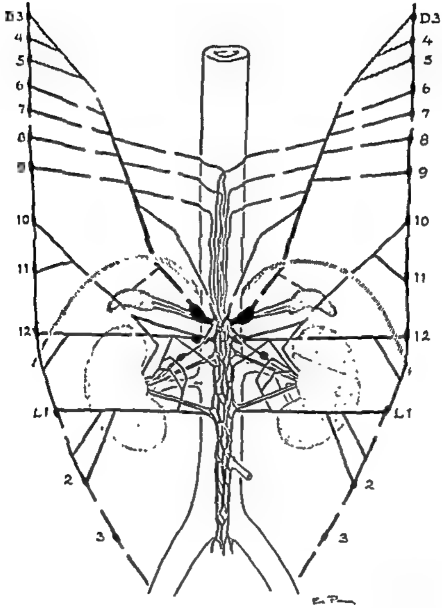

Fig. 15-11. Innervation of splanchnic bed. The origin of the vasoconstrictor pathways to the splanchnic bed is shown in a diagrammatic fashion. It is quite diffuse. From the viewpoint of the great majority of hypertensive patients the splanchnic bed can be adequately denervated by removing the sympathetic trunks from D8 to L1 inclusive, and resecting the great splanchnic nerves from the celiac ganglia to the midthoracic levels.

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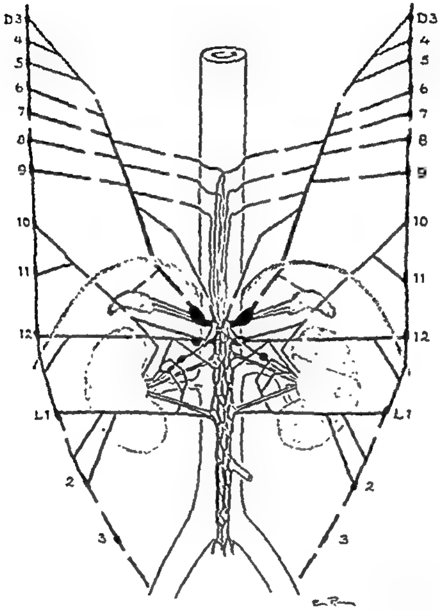

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The diaphragm is next resutured and the renal fascia is then closed with interrupted nonabsorbable sutures (Fig. 15-12). A No. 24F catheter is placed in the extrapleural space to aspirate any residual air which may remain after the wound is closed. If there is an opening in the pleura a second catheter is inserted within the pleural cavity. The lung is expanded with positive pressure and the catheters are removed after the incision has been closed in layers with interrupted sutures.

Following a unilateral lumbodorsal splanchnicectomy, the patients can usually be allowed to dangle the day after operation and are allowed up the next day. No unusual physiologic effects are noted. After the second stage or a bilateral one stage procedure the homeostatic adjustment to the upright position is definitely inadequate. Postural hypotension is not noted after lesser operations and its presence is regarded as conclusive evidence that the splanchnic bed has been thoroughly denervated. As has been previously noted, the degree and duration of postural hypotension depends largely upon the extent of removal of the lumbar chain. It is essential that the patients have a well-fitted abdominal girdle with sponge rubber pads beneath to support the lower abdomen. In addition, Ace bandages should be in place from instep to knee when the patients begin to dangle, generally *two or three days to a week after both sides have been done either in one or* two stages. These patients usually can sit up in a chair after dangling twice a day for two or three days. After sitting twice a day for several days they are allowed to walk with an escort. When upright they should be cautioned not to stand still but to walk slowly from one chair to another. If a patient has had a previous cerebral vascular accident, he should not be mobilized for one week after a unilateral or for two weeks after a bilateral (one stage) procedure. Readjustment begins to occur in two or three weeks and with the less extensive resections, the patients can usually begin to remove the leg bandages one at a time at intervals of one to two weeks starting one month after operation. Following more extensive operations, it may be several months before it is found that the blood pressure in the upright position without apparatus in place does not drop immediately and precipitously on standing. This is the indication to commence the process of removing the supports. After the leg bandages or elastic stockings are dispensed with, the sponge rubber pads are likewise removed, one at a time at similar intervals. The snug lower abdominal girdle is then best worn for an additional two or three months, sometimes longer.

Postoperative discomfort deserves a word of comment. This varies from patient to patient. There are two types of pain. One is a superficial girdle variety associated with hyperesthesia which is undoubtedly due to opera-

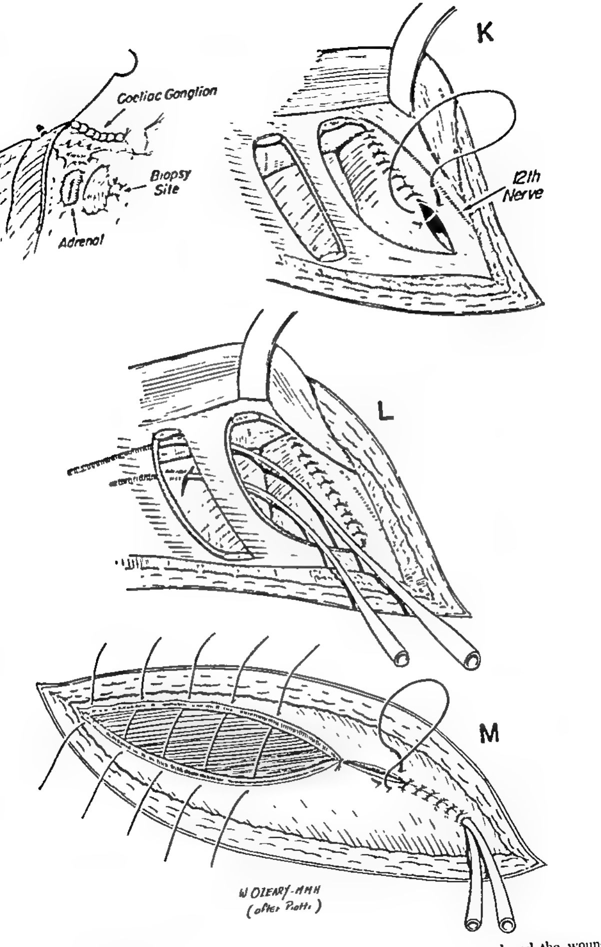

Fig. 15-12. Lumbodorsal splanchnicectomy The diaphragm is resutured and the wound closed carefully in layers Any residual air in the extra- or intrapleural spaces is aspirated and the catheters are then withdrawn

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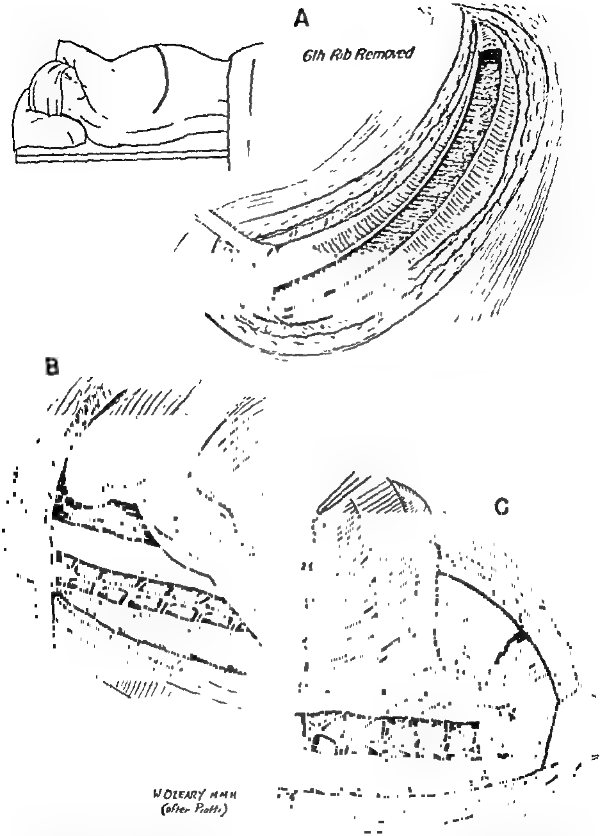


Fig 15-13 Total transthoracic sympathectomy If one desires to remove the thoracic sympathetic chain completely, this can be accomplished through one incision. Most of the sixth rib is resected Proper instruments are required, particularly nerve hooks, forceps, clip applicators, and scissors of proper length.

tive irritation and exposure of intercostal nerves. Every effort should be made to minimize this by gentleness during operation. Local heat together with the application of Baume Bengué or Nupercaine ointment is helpful. Codeine and salicylates generally have to be used. The other type of pain is deep seated, crampy, and appears to be visceral in origin. It is thought to arise in the gastrointestinal tract and is probably the result of hyperactivity of the intestinal smooth muscle in the acutely denervated state. It is associated with obstipation and loss of appetite. It generally disappears or becomes much less marked in a few weeks. Codeine is the most helpful drug during the height of this phenomenon.

Other late sequellae such as increased perspiration in the upper portion of the body in warm weather or cold hands in cold weather should be mentioned. Also, tachycardia, particularly on exertion or after eating, may occasionally persist to a troublesome degree for many months. In over 2,500 cases treated by lumbodorsal splanchnicectomy it has been necessary to denervate the upper extremities in only one case because of the severity of the vasospasm. A few cases have had tachycardia of a degree sufficient to make cardiac denervation advisable. Several cases have subsequently been converted into total sympathectomies because of persistent or recurrent hypertension, so far without much effect other than on heart rate. In several cases, cardiac denervation was subsequently necessary because of troublesome angina pectoris. The late results of lumbodorsal splanchnicectomy are gratifying and it is now apparent that the increased life expectancy of patients with the more severe forms of hypertensive disease treated in this fashion has great statistical significance.

Thoracolumbar Approach to Innervation of Kidney. Occasionally one is confronted with the problem of severe renal colic with no obvious explanation for it. The pain can be reproduced by dilating the ureter or renal pelvis and can be completely relieved by paravertebral novocain block. It can be completely relieved by removing the sympathetic trunk from the tenth thoracic to the third lumbar ganglia inclusive. It is not necessary to remove the great splanchnic nerve. This area is readily exposed by the technic just described for lumbodorsal splanchnicectomy (Figs. 15-9, 10, and 12).

TRANSTHORACIC APPROACHES TO THE SYMPATHETIC NERVOUS SYSTEM AND TO THE VAGUS NERVES

Total or Subtotal Transthoracic Sympathectomy and Splanchnicectomy. A transthoracic approach to either the sympathetic nervous system or the vagus nerves is utilized under certain fairly well defined circumstances. The most frequent indication is to perform a total or subtotal thoracic sympathectomy and splanchnicectomy. This operation is indicated in hypertensive patients who also have either angina pectoris in more than a mild form or who have unusual forms of tachycardia. In the case of hypertensive patients having angina of consequence the sympathetic trunk should be removed from the inferior cervical to the twelfth thoracic ganglia inclusive together with all of the splanchnic nerves arising from this portion of the sympathetic chain. If tachycardia associated with hypertension is the

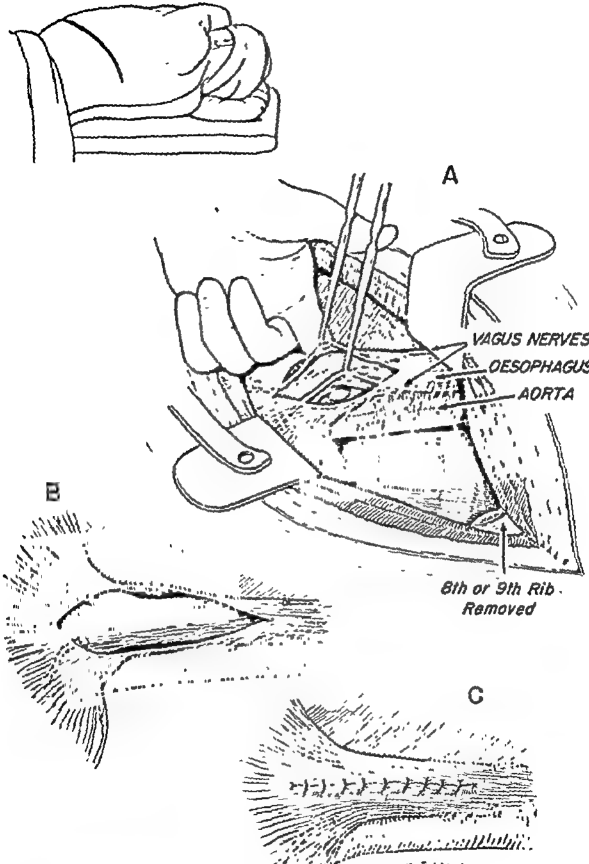


Fig 15-14. Supradiaphragmatic approach to the vagus nerves The various steps employed in resecting the supradiaphragmatic portion of the vagus nerves are illustrated. Adequate exposure by the transpleural route is afforded by resecting the eighth or ninth ribs.

problem, the paravertebral chain together with the splanchnic nerves should be removed from the second to the twelfth thoracic ganglia inclusive. A very good exposure can be obtained for either procedure by removing virtually all of the sixth rib (Fig. 15-13).

The operations are performed in two stages spaced about two weeks apart. With the patient in the lateral position, the sixth rib is resected from the costal margin to the sacrospinalis group (Fig. 15-13). The incision is carefully covered with moist gauze pads and a self-retaining retractor inserted. This gives adequate exposure to remove the entire thoracic chain together with the greater, lesser, and least splanchnic nerves (Fig. 15-13). The inferior cervical ganglion is also readily accessible and should be included when angina pectoris is present. In patients with tachycardia and hypertension without angina, the dissection need not extend above the second thoracic ganglion, but this ganglion must be included. The chest is then closed, leaving two catheters (No. 24F) within the pleural cavity. After the wound is closed, the catheters are withdrawn, any residual air having been aspirated through them with a large asepto syringe while gentle positive pressure is being applied within the trachea. In making and closing chest incisions, we have found it best to avoid the intercostal nerves both during subperiosteal resection of the ribs and the subsequent closure of the wound in layers. No attempt is made to approximate the pleura, and care is taken to avoid including intercostal nerves and vessels in the suture line. As a consequence, there is much less postoperative discomfort. The morbidity and mortality following this operation is greater than following the posterior extrapleural approaches. In poor risk hypertensive patients with coronary heart disease it is wiser to divide the procedure into two stages performing a bilateral supradiaphragmatic splanchnicectomy first and later a bilateral cardiac denervation as previously described, ulitizing the posterior extrapleural approach.

Vagectomy. Transthoracic Approach. Resection of the vagus nerves as a sole therapeutic measure is almost never indicated in the treatment of duodenal ulcer. If, however, a patient develops a gastrojejunal ulcer following a partial or subtotal gastrectomy in which all of the antrum and at least the distal one half of the stomach was removed, a transthoracic resection of the vagus nerves is indicated. To expose the vagus nerves the eighth or ninth rib is resected. The overlying mediastinal pleura is incised from the diaphragm upward to the lung root (Fig. 15-14). This incision in the pleura is anterior to that for the sympathetic chain. The aorta can be readily palpated since the vagi are best approached through the left chest. This furnishes a good landmark, the esophagus lying just anterior to it. The pleural incision is vertical, 1 cm. anterior to the aorta. It is best to divide the inferior pulmonary ligament in order to mobilize the lower lobe of the lung upward. There are usually one or two small vessels in it which require ligation. The pleural incision to expose the esophagus can be placed where the pulmonary ligament has been separated. After the pleura is incised, the esophagus is readily identified and can be lifted up into view and held by moist tape or rubber wicking. The vagus nerves and their intercommunicating branches form a complicated plexus about the esophagus and are intimately related to its outer coat. The two main trunks and all ramifi-

applied tightly. The undermost shoulder is drawn forward. These steps tend to tilt the patient backward toward the operator. Padded supports are placed at the midthoracic and sacral regions. The kidney bar is then elevated, widening the space between the twelfth rib and the iliac crest. This effect can be intensified by lowering the head and foot of the table slightly. The latter is then tilted backward at an angle of about 30 degrees from the horizontal toward the operator.

An incision is then made starting in the angle between the twelfth rib and the lateral edge of the sacrospinalis group. It runs forward, about 1 cm. below the rib to its tip and then curves downward over the posterior edge of the external oblique muscle to the iliac crest (Fig. 15-15) at a point 4 cm. posterior to the anterior-superior iliac spine. As the dissection is deepened, two main muscle groups are encountered lying beneath the deep fascia which is rather ill-defined in this region. In the upper posterior portion of the incision, that running below the twelfth rib, fibers of the latissimus dorsi muscle are cut transversely. In the lower portion of the incision, the external oblique muscle is seen running downward from the tip of the twelfth rib to the iliac crest. This posterior edge of the muscle is elevated and part of its insertion in the iliac crest can be divided. In very heavy set individuals the muscle can be divided transversely a few centimeters above its lower end, but this is rarely necessary. The internal oblique muscle is then seen and its fibers are divided transversely for several centimeters. This is usually a very thin poorly developed muscle layer. Beneath this is the lumbodorsal fascia. This is incised in the direction of its fibers about a centimeter below the twelfth rib, between the twelfth dorsal and first lumbar nerves. The incision is extended posteriorly to the sacrospinalis group and anteriorly to the origin of the transversus abdominis muscle (Fig. 15-15). A finger is then inserted along the twelfth rib, below the lower pole of the kidney and behind the peritoneum and passed over the quadratus lumborum and psoas muscles to the anterolateral aspect of the vertebral bodies. The sympathetic trunk can be readily palpated at this point. The peritoneum is then separated from above downward to the pelvic brim. At this point the common iliac artery can be felt. The sympathetic trunk can be palpated down to and below its third ganglion. The latter is generally just above the common iliac artery.

Moist gauze sponges are packed against the peritoneum over which is placed a wide Deaver type of retractor with light attached. A narrow retractor of similar type can be used posteriorly if necessary over the psoas muscle. The ureter goes forward with the peritoneum. In the depths of the wound anteriorly, the vena cava can be seen on the right and the aorta on the left side. The sympathetic trunk should then be easily seen and felt and is elevated with a long nerve hook. The second ganglion lies approximately in the middle of the field. This is usually a large oval ganglion with two short rami entering its upper pole posteriorly running obliquely from above downward. One ramus leaves the lower pole running obliquely downward and posteriorly to the third nerve. Below this lies the third ganglion usually small and triangular with its rami running obliquely downward and posteriorly to the fourth lumbar nerve. The first lumbar ganglion lies above

cations must be identified, freed from the esophagus and gathered into two bundles, the left or anterior and the right or posterior. These are sectioned below at the diaphragm and crushed and ligated (Fig. 15-14). The lower 4 or 5 inches of the mobilized plexus can readily be resected and the main trunks ligated proximally as well. It is important to be certain that all of the small filaments which may not be included in the main trunks are divided as well. Because of anatomic variations about 10 per cent of vagotomies will be incomplete. In this case, if further surgery is necessary a secondary vagotomy should be performed by the abdominal approach.

LUMBAR SYMPATHECTOMY

Excision of the lumbar portion of the sympathetic trunk is best performed by an extraperitoneal approach. General anesthesia, preferably intratracheal ether, or spinal are used. The latter gives excellent relaxation in heavy set individuals. A posterolateral approach is very satisfactory particularly if one wishes to remove the first as well as the second and third lumbar ganglia. Such a procedure seems indicated if one wishes to denervate the vessels in the thigh as well as the lower leg. An anterolateral approach is also satisfactory for removing the lumbar ganglia, especially the second and third. After an operation of this latter extent, the leg distal to the knee is well sympathectomized. This approach has the advantage of permitting one to do a bilateral procedure in one stage. For this reason it is preferred by most surgeons. In heavy muscular individuals (especially if the anesthesia is not perfect) it may be extremely difficult and even impossible to remove the first lumbar ganglion. If one wishes to denervate the foot in particular, this can be accomplished by removing the third or the third and fourth ganglia. This denervation usually includes the lower third of the leg except in the saphenous distribution. The transperitoneal exposure is more difficult and hazardous and is rarely necessary. Its use should be restricted to young, good risk patients, particularly those in whom there is an additional indication for laparotomy. The principal indications for lumbar sympathectomy are to inhibit vasoconstriction in the presence or absence of known vascular disease, to relieve hyperhidrosis, causalgia, and other post-traumatic syndromes. As in the case of the upper extremity, the presence of Skoog's ganglia in the lumbar region makes it impossible to denervate the leg completely in every case, especially the anterior two thirds of the thigh Regeneration also occurs in time following lumbar sympathectomy but almost never to an extent which detracts from the clinical result.

Posterolateral Retroperitoneal Approach. The patient is placed on the side, with a kidney bar just above the iliac crest. Both thighs are drawn up so that they are at right angles with the abdomen. The legs should be at right angles with the thighs Care should be taken to avoid acute flexion at the knee in patients with obliterative disease. A large soft pillow is placed beneath the under leg and thigh and another between the two legs and thighs. A wide canvas strap is loosely applied over a blanket which covers the legs to keep them in position. The strap should not be

packing is then removed and the wound is easily closed with interrupted nonabsorbable sutures without drainage. The patients are allowed up and about quickly, either the day of or following operation, and generally can be discharged at the end of a week. If both legs are to be sympathectomized the operations are spaced one week apart. If the upper two or three lumbar ganglia are removed bilaterally, loss of ejaculation is very likely to ensue. If the second and third ganglia are removed bilaterally, loss of ejaculation is not infrequent. If the third or third and fourth ganglia are removed bilaterally, loss of ejaculation will rarely if ever result. This also holds for unilateral denervations regardless of the extent. Impotence or loss of orgasm are very rare regardless of the extent of the operations. Loss of sweating occurs in the denervated areas and is compensated for by increased sudomotor activity in undenervated portions of the body.

Anterolateral Retroperitoneal Approach. This technic, which may be used as an alternate to that previously described, is preferred by many. The principal advantage is that it can be performed bilaterally. The disadvantage is that the exposure is not as satisfactory in heavy set or obese individuals, the peritoneum has to be reflected more extensively and is much more easily opened, and the upper portion of the lumbar trunk is less accessible. It is most useful in my experience when bilateral resection of the second and third, third, or third and fourth ganglia is contemplated. With good muscular relaxation one usually can excise the first lumbar ganglion except in extremely heavy set individuals. With the patient in the horizontal position, a transverse incision is made at the level of the umbilicus extending from the lateral border of the rectus muscle to the flank (Fig. 15-16). The superficial fascia and the fascia of the external oblique are divided transversely including a centimeter or two of its muscle fibers in the lateral portion of the wound. The internal oblique muscle is split in the direction of its fibers for about 8 cm. A similar incision is made in the transversus abdominis muscle (Fig. 15-16). The peritoneum is then carefully separated from the quadratus and psoas muscles as previously described. It is easy to open the peritoneum and also to get in a wrong plane of cleavage deep to the psoas muscle. Care must be taken not to damage the vena cava and the lumbar veins. More active retraction of the vena cava is needed in this approach as it overlies the sympathetic trunk. It is usually more difficult to be as certain what portion of the trunk is being removed by this exposure. There may be some uncertainty on this point in any technic because of the frequent anatomic variations which may be encountered. The sympathetic trunk is elevated on a long nerve hook, and the desired portion removed (Fig. 15-16). Silver or tantalum dura clips should be applied to the resected ends of the trunk and to all divided rami. These are readily demonstrable in postoperative films and are useful in confirming the extent and level of the resection. The wound is then easily closed with interrupted nonabsorbable sutures without drainage. The operation can be performed bilaterally if desired. The postoperative convalescence is usually rapid and the patients can be up and about the following day and discharged in 8 to 10 days.

Subdiaphragmatic Splanchnicectomy. This technic for denervation of the splanchnic bed has been utilized largely in the treatment of hyperten-

the second usually under cover of a thin layer of fascia which closes the medial lumbocostal arch. This is divided vertically, if necessary. The rami to this ganglion are fairly long and enter it posteriorly running obliquely from above downward (Fig. 15-15). One must be on the lookout for the lumbar veins, particularly on the right side, and especially at the first and

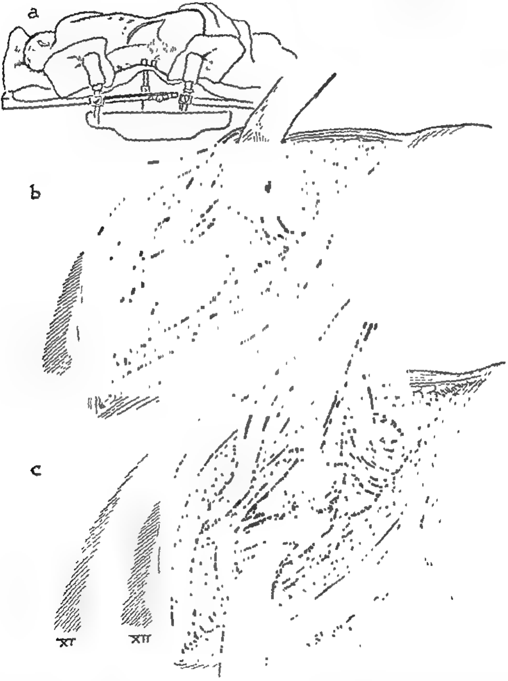


Fig. 15-15 Lumbar sympathectomy This portion of the sympathetic trunk can be approached by a posterolateral retroperitoneal exposure. This approach is particularly useful if one desires to remove the first lumbar ganglion in addition to others, and for unilateral procedures.

third lumbar levels. While these veins do not as a rule cross anterior to the sympathetic trunk, occasionally they may If this is not detected they can be injured. Profuse bleeding will ensue which may be difficult to control. The desired portion of the sympathetic trunk is removed, dural clips being applied to its proximal and distal ends and to all divided rami. The gauze

sion but can also be utilized for motor and sensory denervation of the abdominal viscera. The reported results of this operation in hypertensive patients include many which are temporary in nature. This, I believe, is due to the limited extent of resection of the great and lesser splanchnic nerves which this exposure permits. Consequently, regeneration may take place in a comparatively short time. I personally have had occasion to re-operate upon a number of these patients and have found that the great splanchnic nerve had regenerated presumably within six months to two years after the original procedure. Following secondary operations, the hypertension has again been favorably modified in some cases. In one patient suffering from a neurogenic motor disorder of the colon simulating intestinal obstruction, symptoms were entirely relieved by a subdiaphragmatic type of splanchnicectomy in which 3 cm. of the great splanchnic nerves were removed in addition to the lumbar trunks. Seven months later the symptoms suddenly recurred. These were again relieved by a secondary supradiaphragmatic transpleural operation at which the left great splanchnic nerve was found to be completely regenerated. A few months later, symptoms again recurred and were relieved by a third operation consisting of a transpleural resection of the right great splanchnic nerve. This also was found to have completely regenerated. It is my belief that the subdiaphragmatic technic is not a satisfactory operation for denervation of the splanchnic bed. It is consequently not illustrated here.

TRANSPERITONEAL APPROACH TO THE SYMPATHETIC NERVOUS SYSTEM AND THE VAGUS NERVES

The indications for employing a transperitoneal approach to the sympathetic nervous system are few indeed. While this approach can be utilized for lumbar sympathectomy, these operations are best performed by the retroperitoneal technics already described. The only reason for laparotomy would seem to be when some additional indication exists, such as an ovarian cyst or vascular disease requiring grafting or similar procedures. The only advantage is that both extremities can be denervated at one time. This can also be more easily accomplished by an extraperitoneal technic. On the other hand the transperitoneal route is the exposure of choice for resecting the presacral and the vagus nerves.

Lumbar Sympathectomy. In case transperitoneal lumber sympathectomy is to be performed, a long right paramedian incision should be made extending from the costal margin to well below the umbilicus. Spinal or intratracheal ether anesthesia is indicated. The right rectus muscle is retracted laterally. The peritoneum is opened, and the patient placed in the Trendelenburg position. The intestines are gently and carefully walled off with moist gauze packs. The parietal peritoneum is divided lateral to the cecum and ascending colon on the right and the sigmoid and descending colon on the left. The bowel and mesentery are reflected toward the midline. Retroperitoneal dissection is then carried out exposing the sympathetic trunk on the anterolateral aspect of the lumbar spine behind the vena cava on the right and just to the left of the aorta on the left. The trunks can be readily identified by palpation. It is comparatively easy to

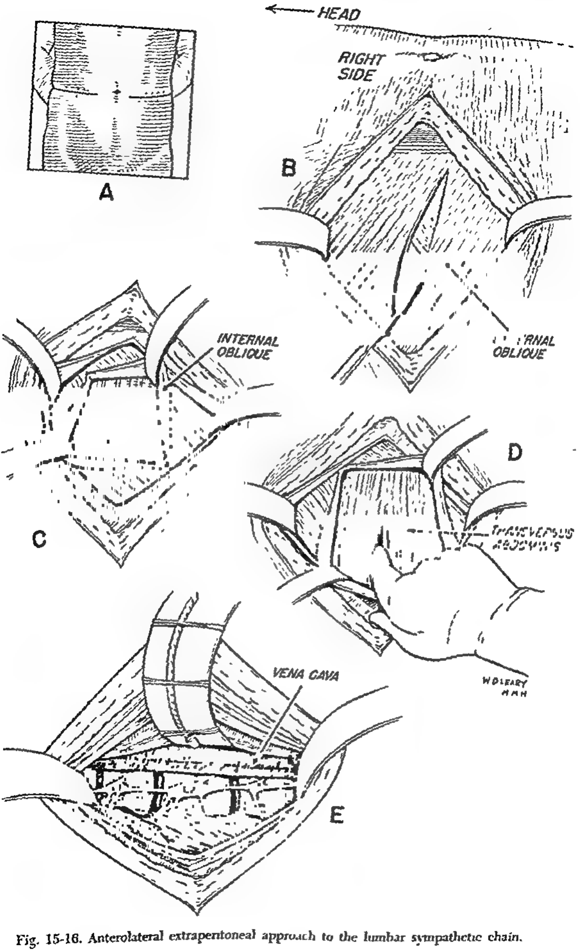


Fig. 15-16. Anterolateral extraperitoneal approach to the lumbar sympathetic chain.

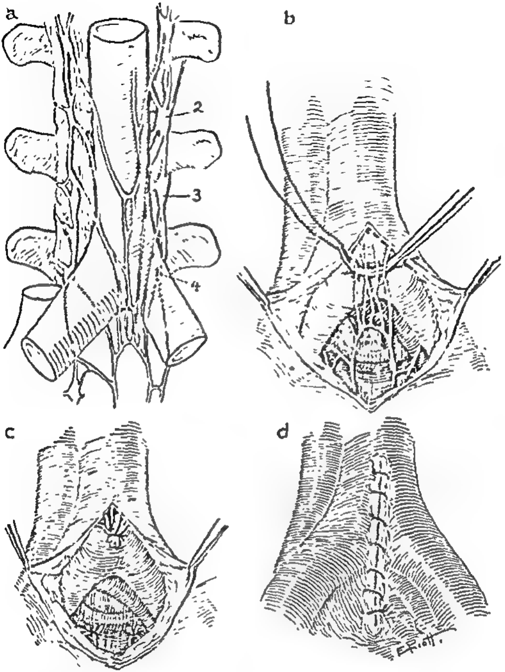


Fig 15-17. Presacral neurectomy This portion of the sympathetic nervous system is exposed by laparotomy Resection of the presacral nerve is helpful in the management of severe dysmenorrhea.

Many surgeons prefer a left paramedian incision for the abdominal approach to the stomach and the vagus nerves, mobilizing the left lobe of the liver as indicated in Figure 15-18. This exposure is very satisfactory, especially for radical subtotal gastrectomy. However, in my experience, it does not seem necessary to do radical gastrectomies if the vagus nerves are also to be resected. Removal of the distal half of the stomach combined with vagotomy has as great an effect upon gastric acidity as does a more radical gastric resection combined with vagotomy. The clinical results of the less radical combined procedure are superior. Since a hemigastrectomy can be performed with facility through a right paramedian incision and since this gives a better exposure of the duodenum and an equally, if not

remove the third or the third and fourth lumbar ganglia. The second can as a rule be excised without too much effort. It is usually difficult or impossible and unduly traumatic to the intestine and mesentery to remove the first lumbar ganglia. Careful hemostasis must be obtained and the trunks and rami should be carefully clipped as previously described. The intestine is then allowed to fall back into place and the parietal peritoneum is carefully sutured. The appendix can be removed, or an ovarian cyst can be excised. The abdominal wall is then closed carefully in layers without drainage. This technic is unnecessarily hazardous and should only be employed, and then rarely, in young healthy individuals and never in the older age group.

Presacral Neurectomy. The principal indication for resection of the presacral plexus is the relief of dysmenorrhea. This operation can be expected to be worth-while in about 75 per cent of intractable cases of this sort, but should be combined with gynecologic procedures such as dilatation of the cervix and suspension of the uterus when advisable. A median suprapubic or a left paramedian incision is made as in the performance of any pelvic operation. The choice of incision depends upon the build of the patient, obesity, and other recognized considerations. Ether or spinal anesthesia is used. The Trendelenburg position is necessary. After opening the abdominal wall, the intestines are gently retracted upward with moist gauze packs and an incision is made in the midline in the posterior peritoneum overlying the bifurcation of the aorta and extending downward over the sacral promontory. The edges are held by interrupted traction sutures and peritoneal flaps dissected to visualize the iliac vessels and ureters laterally. The descending sympathetic fibers which form the plexus are elevated on a nerve hook at the aortic bifurcation. These are ligated proximally and divided. The distal ends of the divided filaments are held in a half-length and followed distally for several centimeters and laterally to the great vessels. The distal portion is ligated and divided in segments. After being certain that hemostasis is complete, the posterior peritoneum is closed with a fine continuous atraumatic suture and the abdominal incision is closed carefully in layers without drainage (Fig. 15-17).

Resection of Vagus Nerves. Resection of the vagus nerves is proving to be a valuable adjunct in the management of refractory duodenal ulcers requiring surgical treatment. As a sole procedure it has little merit, but when combined with operations upon the stomach itself, it appears to be very helpful. For this reason, the abdominal approach to the vagus nerves is necessary in the great majority of cases. Only rarely is the transthoracic technic employed and the principal indication for using it is to resect the vagus nerves when a gastrojejunal ulcer has developed following a gastric resection in which at least the distal one half of the stomach including the antrum has been removed. One other indication is to do a secondary vagotomy when a previous resection of the vagus nerves performed through the abdominal approach is found to be incomplete and a clear indication for making the resection complete exists. There still is controversy about the operation of choice for duodenal ulcer patients. There is no doubt that many surgeons, including the author, believe that combined procedures hold great promise especially hemigastrectomy combined with vagotomy.

trunks of the vagus nerve are then separated from the esophagus manually and 3 or 4 inches of each is resected, ligating them proximally and distally as shown in Figure 15-19. The left or anterior trunk is resected first and then the right or posterior is treated in a similar fashion. Actually, the right vagus nerve is *not posterior* to the lower end of the esophagus but is lateral to it being 1 to 1.5 cm. to the right. It is not in close contact with the wall of the esophagus as is the left trunk. There are many variations in the distribution of the vagus trunks in relation to the lower end of the esophagus.

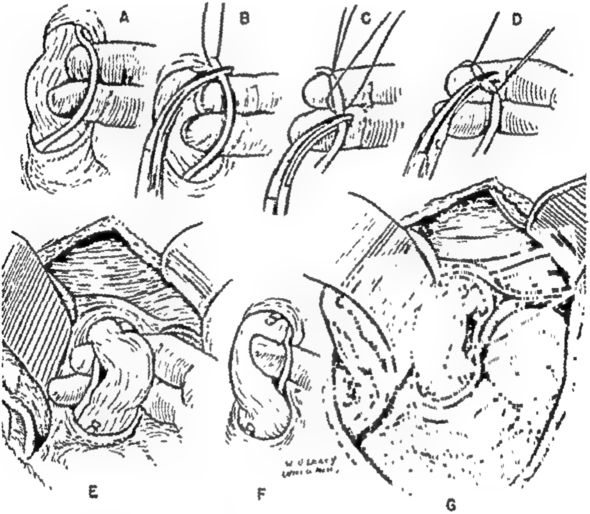


Fig. 15-19. Transabdominal vagectomy. Technic of resection. (After Dragstedt et al. Ann. Surg., 126:678, 1947.)

Because of this one must palpate carefully for fine filaments which may not be contained in the main trunks or which may take their place. The incidence of incomplete vagotomies will depend largely upon anatomic variations and the acuteness of the surgeon's sense of touch. Experience, of course, is also very important. It is best to complete the vagotomy before any gastric surgery is done to minimize the contamination which will necessarily result if open procedures are performed upon the stomach. The author prefers to use a closed (aseptic) technic whenever possible in all portions of the gastrointestinal tract.

more satisfactory, exposure of the vagus nerves, it is recommended as the incision of choice for vagotomy. It also is far superior to a transverse incision especially in individuals who have a narrow space between the costal margins. It is not necessary to mobilize the left lobe of the liver if a right paramedian incision is used.

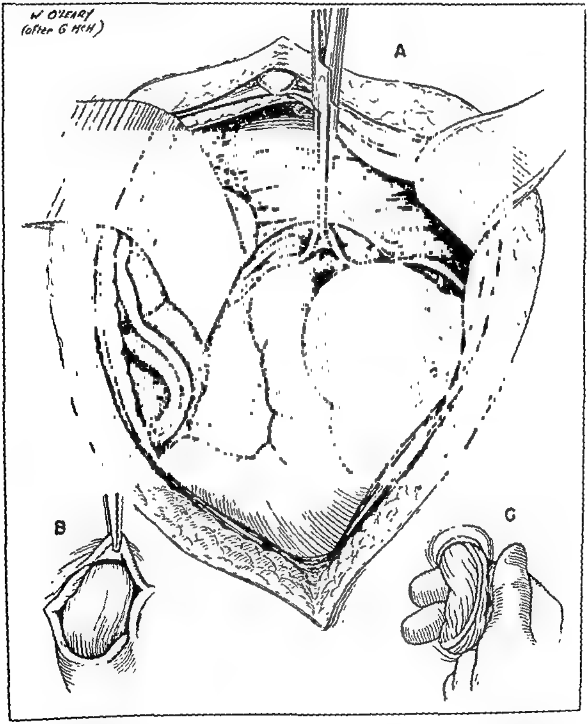
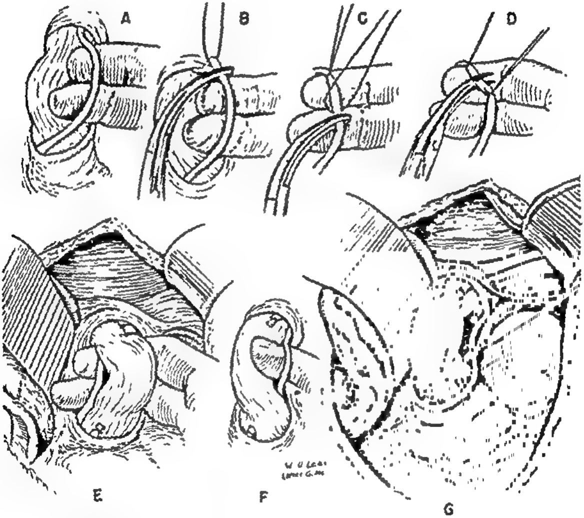


Fig. 15-18. Transabdominal vagotomy Exposure of vagus nerve (After Dragstedt et al. Ann. Surg., 126.678, 1947)

After a good exposure of the upper abdomen through one incision or another is obtained, the peritoneum is incised transversely over the lower portion of the esophagus and the latter is readily mobilized by gentle finger dissection as indicated by the inserts in Figure 15-18. The main

trunks of the vagus nerve are then separated from the esophagus manually and 3 or 4 inches of each is resected, ligating them proximally and distally as shown in Figure 15-19. The left or anterior trunk is resected first and then the right or posterior is treated in a similar fashion. Actually, the right vagus nerve is not posterior to the lower end of the esophagus but is lateral to it being 1 to 1.5 cm. to the right. It is not in close contact with the wall of the esophagus as is the left trunk. There are many variations in the distribution of the vagus trunks in relation to the lower end of the esophagus.



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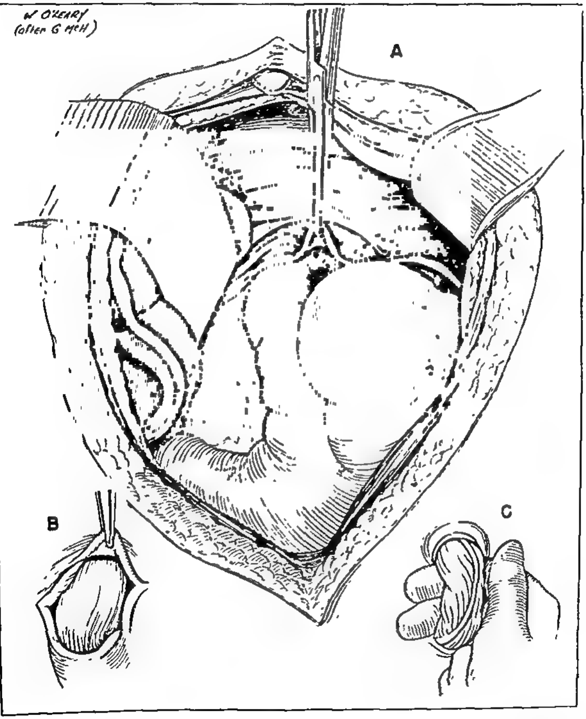

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sleep, eat, and no longer require opiates. This increases the opportunity for development of a collateral circulation. Many extremities which otherwise would have to be sacrificed by major amputations have been saved. The incidence of successful minor amputations has increased materially. This procedure applies chiefly to the lower extremity but is occasionally indicated in the management of vascular disease of the upper extremity. It is usually advisable to sympathectomize the extremity at a later date when healing of ulceration and survival of the extremity seem assured.

The technic of operation must be meticulous. Detailed knowledge of the exact location of the peripheral nerves in question is essential. In the case of the lower extremity there are five to be considered (Fig. 15-20). Each of these can be exposed by a small vertical incision in the middle or upper third of the leg. The nerve in question is simply crushed with a hemostat. This produces temporary anesthesia and vasomotor paralysis. Regeneration occurs in several months. The more important motor fibers can be avoided. Only one nerve should be crushed at a time. It may be necessary to crush several depending upon the location and size of the ulceration. Local anesthesia is generally used, rarely spinal. Any bleeding points are ligated with fine catgut or silk and the skin closed with interrupted silk sutures, so placed as to assure perfect approximation of skin edges, and so tied as to avoid ischemia.

PARAVERTEBRAL SYMPATHETIC BLOCK

The sympathetic rami and ganglia can be blocked paravertebrally with procaine. The effect is temporary but serves as a diagnostic test. For a more lasting effect, ethyl alcohol, 95 per cent, or absolute, can be injected in 3 to 5 ml. amounts in each needle. It is important that the novocain injection be accurate and that the desired physiologic effect be apparent before the alcohol is injected. Alcohol should be injected very slowly at a rate of not over 1 ml. per minute. This tends to limit its diffusion. In spite of all precautions, however, some is almost certain to reach adjacent peripheral nerves particularly in the upper thoracic region. The result is a very painful and persistent form of peripheral neuritis. This appears, as a rule, several days after injection It may last weeks or months. It constitutes a serious objection to chemical sympathetic block as a therapeutic measure. Its use should be largely confined to the treatment of intractable visceral pain, particularly angina pectoris, in cases in which the risk of surgical excision is deemed too great.

There are hazards also to paravertebral novocain block, especially in the thoracic region, and particularly in inexperienced hands. One must make certain by frequent aspiration that the needle is not in the spinal canal, in a blood vessel, or within the parenchyma of the lung. One should never attempt these blocks without having previously attained proficiency as the result of practice upon the cadaver All patients should be given some form of barbiturate in appropriate dosage (i.e., nembutal, 100 mg.) one-half hour prior to the novocain block to prevent or minimize reactions. Paravertebral novocain block has been found to be useful in the management of minor causalgias and deep thrombophlebitis involving the femoral

PERIPHERAL SYMPATHECTOMY

This procedure has proven to be a useful adjunct to the management of the peripheral vascular disease under certain definite circumstances. It is indicated in patients with chronic obliterative vascular disorders having painful localized gangrene or ulceration. The purpose is threefold,

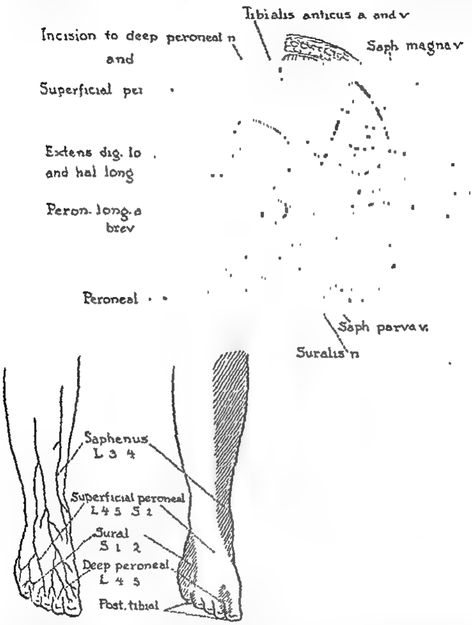

Fig. 15-20. Peripheral sympathectomy In this operation, vasoconstrictor fibers to the cutaneous vessels of the foot may be temporarily inactivated by crushing the sensory nerve supply to a given area Temporary anesthesia without interruption of important motor fibers also results. This procedure is helpful in the management of obliterative vascular disorders when painful localized ulceration or gangrene is present and the collateral circulation is satisfactory (From Homans *Textbook of Surgery* Courtesy Charles C Thomas Co)

first, to relieve pain; second, to thereby permit adequate local dressings which in turn facilitates the control of infection, and third, to interrupt sympathetic impulses and thereby increase circulation because of temporary inhibition of vasoconstriction It allows a period of palliation during which the general condition of the patients improves because they can

breadth above the clavicle and just medial to the sternomastoid tendon. An 8 cm. No. 19 gauge needle with a rubber marker threaded onto it and placed about 3 cm. from the tip is introduced posteriorly through the wheal in the parasagittal plane. The patient is in the horizontal position with the neck slightly extended over a small firm pillow. A 10 ml. syringe containing a few milliliters of 1 per cent novocain is attached to the needle. The latter is slowly introduced during which process the syringe is aspirated frequently to be certain that it is not in a vessel or in the spinal canal, and from time to time a small amount of novocain is introduced if necessary. The procedure should be painless. The tip of the needle passes just lateral to the trachea and esophagus and medial to the great vessels (Fig. 15-21). The point should strike the spinal column on its anterolateral aspect at a depth of 3 to 5 cm. and at the level of the seventh cervical vertebra at which it should lie close to the stellate ganglion. About 5 to 10 ml. of 1 per cent novocain is slowly introduced. A Horner's sign should appear promptly. This technic is quite certain to denervate the blood vessels of one side of the head and neck but may not always completely denervate the upper extremity if the novocain solution fails to diffuse downward to the level of the second thoracic ganglion.

The stellate ganglion can also be injected by a posterior approach. The author prefers this for patients who can sit up. With the patient in this position with the head and neck exactly in the midline and the head slightly flexed, an intradermal wheal of novocain is placed directly lateral to the spinous process which lies immediately above the *first* of the most prominent spinous process at the base of the neck (Fig. 15-22). These are generally the seventh cervical and the upper two thoracic. The novocain wheal therefore usually lies lateral to the spinous process of the sixth cervical vertebra. It should be placed 1 cm. medial to the lateral skin line of the neck. This point will vary from 2½ to 4 cm. from the midline depending upon the muscularity of the individual. The needle with attached syringe is slowly introduced almost vertically downward with the point tilting medially about 20°. It is helpful to palpate the first rib in the supraclavicular fossa paravertebrally just anterior to the lateral border of the trapezius muscle. The purpose is to contact the upper surface of the rib near its posterior edge (Fig. 15-22A). The plane of the rib is such that once its upper surface is contacted the needle with a slight adjustment in direction can be inserted along the upper surface of the first rib to a depth of 1 to 3 mm. beyond its anterior border (Fig. 15-22B). The tip of the needle is not in contact with bone at this point and it lies in very close relation to the lower portion of the stellate ganglion. Once contact is made with the first rib during the insertion of the needle, the rubber marker should be placed 1 cm. above the level of the skin. As the needle passes inward along the upper surface of the rib its tip should reach the anterior border of the rib just as the rubber marker reaches the skin. As indicated above, the needle is introduced a little deeper during which time the syringe is aspirated repeatedly and a small amount of novocain injected in order to get the tip of the needle in the right cleavage plane. This is reached when there is a slight resistance to the introduction of the novocain. If it is difficult to inject the novocain it means that the tip of the needle is

and iliac veins with phlegmasia alba dolens. It is an interesting way to study vasomotor reactions of the extremities in peripheral vascular disorders and was used extensively by pioneer investigators. However, other methods of study have been devised so that it no longer is a necessary routine diagnostic procedure. It is my feeling that these injections should be done only by individuals who have made a careful study of the technic and who have a particular interest and reason for performing them. While any portion of the sympathetic trunk can be blocked paravertebrally, the most common indications are temporary denervation of the extremities and alcohol injection for the relief of angina pectoris. Viscerosensory pathways can also be blocked and at times this may be of some diagnostic and therapeutic value. In most hands, however, blocking the splanchnic nerves is apt to be difficult and the results equivocal.

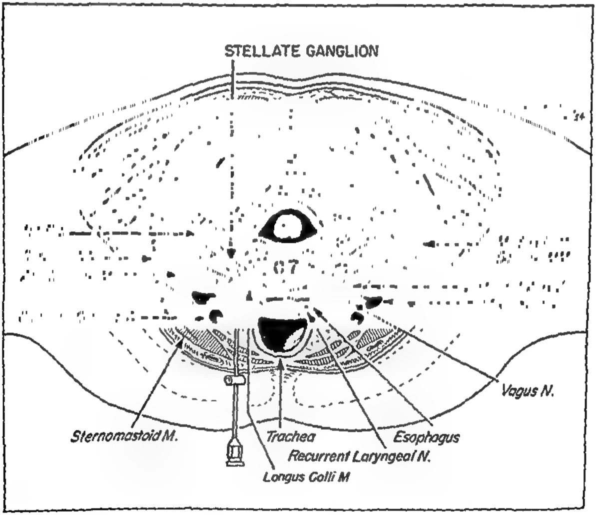

Fig. 15-21 Cross section lower cervical region showing structures to be avoided in the anterior approach to injection of the stellate ganglion

Stellate Block. This is a relatively simple way to temporarily interrupt the sympathetic supply to the head and upper extremity. There are numerous indications for this both from a diagnostic and therapeutic viewpoint. There are two satisfactory technics, an anterior and a posterior. The anterior approach is most useful if it seems best to have the patient in the horizontal position. An intradermal wheal of novacain is placed two finger's

satisfactory and the gauge should be No. 19 (Fig. 15-23c, d). The needles should be at least 8 cm. long and preferably 10 or 12. A rubber marker should be threaded on each. Shorter needles attached to a 5 ml. syringe are used to infiltrate novocain down to the rib. The longer needle is then attached to the syringe containing 1 per cent procaine and inserted in a direction normal to the skin until contact is made with the rib. The lower

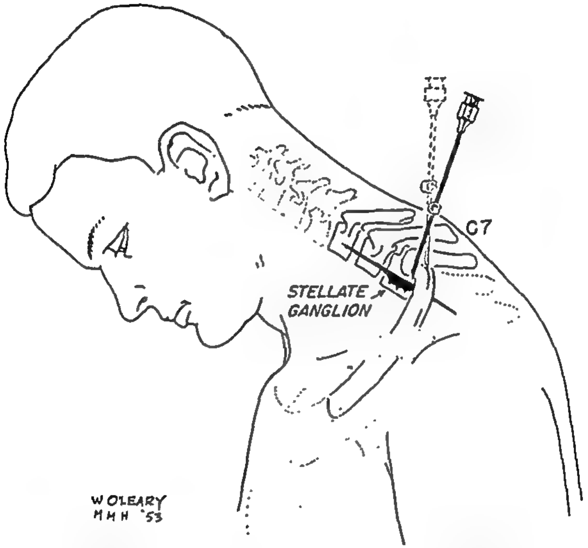

Fig. 15-22 (cont.). After contacting the posterior edge of the first rib, the direction of the needle is changed so that its tip is in contact with the superior surface of the rib as it is inserted deeper for about 1 cm

edge of the rib is located and at this point the rubber marker is set 4 cm. from the skin. The point of the needle is then directed at an angle of about 30° downward and medialward. The needle is advanced slowly and below the lower edge of the rib and should contact the side of the vertebral body at a depth of not over 4 cm It is unwise to insert the needle deeper. Instead, the direction should be changed so that the tip is advanced medialward at an angle of 35° or 40° If bone is contacted too superficially, it probably means that the resistance is being offered by a transverse process or the underlying rib rather than the vertebral body. In this case the needle has been inserted at too great a downward angle, so this is lessened toward the vertical. When the needle is in good position, the syringe is carefully

buried in very dense tissue. Consequently the solution will not diffuse. If the solution enters too readily it may diffuse too rapidly. About 5 to 10 ml. of 1 per cent novocain is used. This technic probably sounds complicated. Actually it is not. It is safe provided proper precautions are followed. It is very accurate and results in an almost instantaneous denervation of the head, neck, and upper extremity in almost every case.

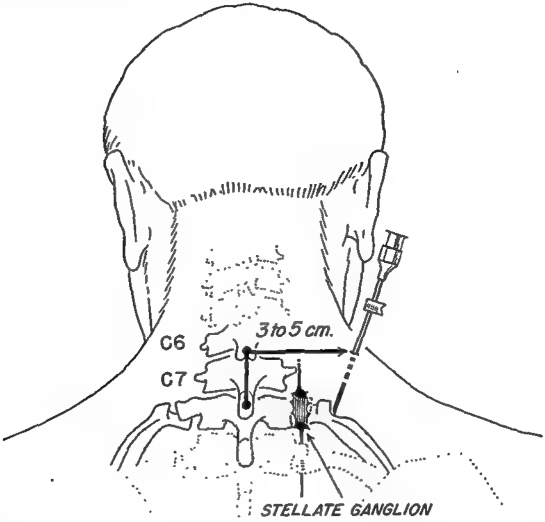

Fig. 15-22 Injection of the stellate ganglion by the posterior approach The needle is introduced in a downward direction through a skin wheal placed 3 to 5 cm lateral to the tip of the sixth cervical spinous process and 1 cm medial to the lateral skin line of the neck until contact is made with the posterior edge of the first rib

Thoracic Paravertebral Block. To block the sympathetic supply to the upper extremity, the patient may either be in a sitting position or may lie on one side, that to be blocked being uppermost. If the patient is high strung and hypersensitive, it is best to have him lie on the side. This is generally best in patients with angina pectoris. The upper dorsal and lowest cervical spinous process are marked and nocovain wheals are elevated 3½ to 4 cm. lateral to the spinous processes. The wheal lateral to the seventh cervical spinous process will lie over the first rib, and those opposite the upper dorsal spinous processes will lie over the rib below rather than the corresponding one. This is due to the long downward projection of the spinous processes in this region. Needles of the lumbar puncture type are

surface until the anterior border is passed as already described in the preceding section on stellate block. To denervate the heart, needles are inserted beneath the upper four ribs.

Lumbar Paravertebral Block. The patient is placed on his side in much the same position as for lumbar puncture. The side to be injected is uppermost. The lumbar spinous processes are readily palpated. A perpendicular line dropped from the iliac crest will usually cross the midline between the third and fourth spinous processes. A perpendicular line dropped from the lower edge of the twelfth rib 7 cm. long will usually contact the twelfth thoracic spinous process. From these landmarks, one can identify the lumbar spinous processes with reasonable accuracy. The transverse processes lie half way between the spinous processes, and opposite the space above the corresponding spinous process. Intradermal novocain wheals are raised 3½ to 4 cm. lateral to the midline, over the transverse processes, that is, half way between the two spinous processes (Fig. 15-23a, b). A fine 4 cm. needle is then attached to the syringe and inserted normal to the skin, infiltrating ahead of the needle which is slowly inserted until contact is made with the transverse process. Novocain is then injected at this point and the needle tilted to locate the lower edge of the process. More novocain is injected at this point, perhaps a milliliter or two. A 10 or 12 cm. lumbar puncture type of needle with a rubber marker threaded upon it is then attached to the syringe and inserted as above until contact is made with the transverse process, usually at a depth of 3 to 4 cm. The marker is then placed 4 cm. from the skin, the direction of the needle changed to pass either just above or below the transverse process and toward the midline at an angle of about 20° from the vertical. It is inserted slowly in this direction, and contact should be made with the side of the body of the lumbar vertebra at a depth of approximately 4 cm. below the level of the transverse process. If contact is made sooner, the direction of the needle is changed toward the vertical and reinserted. If contact is not made at this depth, the direction is changed slightly away from the vertical and the needle is reinserted. If paresthesias are obtained, the needle is changed slightly. These are less frequent, in my experience, if the needle is inserted just above rather than below the transverse process. Procaine can be injected in small amounts as the needle is inserted if the maneuver is painful. Frequent aspiration is advisable before injecting novocain. When the needle is properly placed, 5 ml. of novocain 1 per cent is injected. To denervate the lower extremity, two needles inserted at the level of the first and second lumbar transverse processes will usually suffice. A third needle at the third lumbar transverse process is usually unnecessary. There is no objection to injecting 10 ml. of novocain in each needle if alcohol is not to be used. If it is, 3 to 5 ml. of alcohol can be injected slowly in each needle if the desired physiologic effect has been obtained from the original novocain injection which should not exceed 5 ml. in each needle. Painful peripheral neuritis may result, as after thoracic paravertebral block. It is generally advisable to put 2 or 3 drops of adrenalin 1:1000 solution in 4 ounces of 1 per cent novocain. A sterile centimeter rule should be part of the equipment.

aspirated to be certain that spinal fluid, blood, or air do not come out. About 5 ml. of novocain 1 per cent is then slowly and gently instilled, aspirating from time to time. If alcohol is to be injected, this is done as previously described, very slowly, in 3 to 5 ml. amounts in each needle, only after the

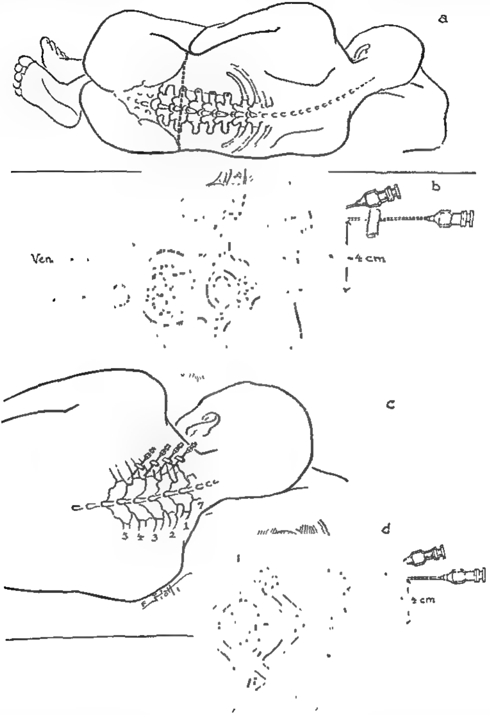

Fig 15-23. Paravertebral block All portions of the sympathetic trunk can be blocked by injecting novocain paravertebrally This procedure is most commonly used in the study of peripheral vascular disorders and visceral pain problems The technic of lumbar and thoracic block is illustrated.

desired physiological response to the novocain is manifest. To block the upper extremity, needles are inserted beneath the upper two ribs An alternate technic is to insert the needle above the first rib, passing it just beyond the anterior edge of the rib, keeping it in contact with the superior

16

PERIPHERAL NERVES

R. Glen Spurling

The experiences with peripheral nerve surgery in World War II have logically laid the groundwork for all future civilian practices—*until the next war.* These lesions are so relatively infrequent in civilian life that no single individual can hope to accumulate enough data to change radically the present concepts which have been tested upon many thousands of cases. Not that the present treatment policies are perfect—far from it—yet the results of treatment of some 20,000 peripheral nerve casualties by several hundred neurosurgeons have been better, from the standpoint of functional recovery, than any heretofore known.

It is extraordinary how frequently nerve lesions are overlooked even by physicians who are otherwise highly trained in the management of trauma. No doubt this is due to the surgeon focusing his primary interest upon the *fractured bone, the mutilating soft tissue wound, or the emergency* accompanying major vascular injuries. Once the damaged extremity is encased in a plaster cast, the associated nerve injury may go unrecognized for weeks or even months. It has been established beyond reasonable doubt that the early repair of severed nerves yields the best functional results. Therefore, it becomes mandatory that the nerve injury be recognized by the surgeon who first treats the patient.

Complicated clinical and laboratory examinations are not necessary in recognizing the more common nerve injuries.* As an example, the integrity of the main nerve trunks of the upper and lower extremities can be evaluated with considerable accuracy by studying the movements of the *thumb* and *great toe*(9).

UPPER EXTREMITY

Median Nerve. Figure 16-1 illustrates position of the thumb which cannot be reproduced when the median nerve is interrupted proximal to the wrist. The first metacarpal is flexed at the wrist, a motion primarily accomplished by contraction of the opponens pollicis. In addition, the distal phalanx of the thumb is extended on the proximal and the whole thumb is rotated inward so that the palmar surface of the distal phalanx opposes the palmar surface of the other digits. This position can be reproduced only with good contraction of the abductor pollicis brevis and the outer head of the flexor pollicis brevis. These three muscles are supplied through a muscular branch of the median nerve which arises just distal to the annular ligament. If the thumb can be maintained in this position, no

* The *monograph of Haymaker and Woodhall* is an indispensable volume for those dealing with peripheral nerve injuries. All of the most useful clinical tests are meticulously described and explained by *anatomic descriptions, photographs, and drawings.*

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other examination is necessary to establish the functional integrity of the median nerve.

Ulnar Nerve. Figure 16-2 illustrates the position of the thumb which cannot be maintained when the ulnar nerve is interrupted proximal to the wrist. The first metacarpal is held in the plane of the other four. The proximal phalanx of the thumb is slightly flexed and is pulled toward the metacarpal and metacarpophalangeal joint of the index finger. This function can be tested readily by the patient's ability to hold a stiff piece of paper when an attempt is made by the examiner to withdraw it in the manner illustrated.

The muscles which produce this action are the adductor pollicis and the inner head of the flexor pollicis brevis. These two muscles are supplied by the terminal muscular branches of the ulnar nerve within the palm. If this position of the thumb cannot be held in the absence of local injury, further examination is unnecessary to establish functional impairment of the ulnar nerve.

Radial Nerve. Figure 16-3 illustrates the position of the thumb which cannot be maintained if the function of the radial nerve is interrupted proximal to the wrist. The first metacarpal is directly abducted at the carpometacarpal joint in the plane of the palm. The proximal and distal phalanges of the thumb are both held in extension. This position is made possible by contraction of the extensor pollicis brevis aided by the weaker abductor pollicis longus. These two muscles are supplied in the hand by the terminal muscular branch of the posterior interosseous division of the radial nerve. If this position of the thumb cannot be maintained in the absence of local injury, further examination is unnecessary to establish functional impairment of the radial nerve.

The radial nerve is most likely to be injured in the upper arm and, when this is true, confirmatory evidence is found in the hand by inability to extend both the proximal and distal phalanges of the thumb, a function accomplished by contraction of the extensor pollicis longus. Also, inability to extend the first phalanges of the other digits on the metacarpals results from paralysis of the extensor digitorum communis. Both of these muscles are innervated by muscular branches of the radial nerve in the proximal third of the forearm. Care must be taken not to confuse extension at the metacarpophalangeal joints with extension at the interphalangeal joints since the latter is a function of the lumbricales and interossei.

LOWER EXTREMITY

The intrinsic musculature in the foot is not developed to the same extent as in the hand so that reliable observations must be limited to simple contractions of the long flexors and extensors of the toes or else include movements of the entire foot. Fortunately, injuries of the lower extremity which involve peripheral nerves are commonest high in the thigh and about the knee. In the former location either or both divisions of the sciatic nerve may be involved. In the latter the common peroneal nerve is damaged most frequently. Because of this, examination of the toes will give valuable information in the majority of lower extremity

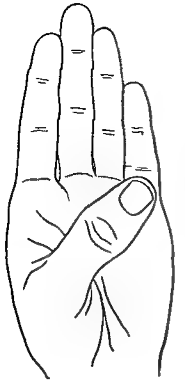


Fig. 16-1. Test for median nerve function. Thumb is flexed at the wrist and rotated inward so that the palmar surface of the distal phalanx of the thumb opposes palm of hand. Distal phalanx is extended on the proximal. The ability to maintain the thumb in this position indicates that the function of the median nerve has not been impaired proximal to the wrist (From Spurling, R. G., and Matson, D. D. Army M. Bull., 75:72, 1944.)

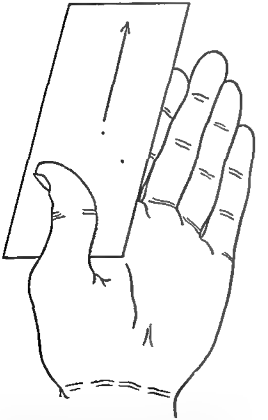


Fig 16-2. Test for ulnar nerve function Thumb is held in plane of the palm and pulled toward metacarpal of index finger. A piece of stiff paper is placed between the thumb and index finger When the ulnar nerve is intact, the patient will be able to hold the piece of paper against considerable pressure when the examiner attempts to withdraw it (From Spurling, R. G, and Matson, D D Army M Bull., 75.73, 1944.)

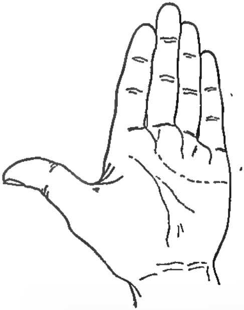


Fig. 16-3. Test for radial nerve function Thumb is abducted at the wrist in plane of palm and proximal and distal phalanges of thumb are extended If this position of the thumb can be assumed in the absence of local injury, it indicates that the function of the radial nerve has not been impaired. (From Spurling, R. G, and Matson, D D. Army M Bull, 75 74, 1944.)

hallucis longus and flexor hallucis brevis. These muscles are supplied by the tibial nerve in the proximal third of the lower leg. If this position of the toe cannot be maintained in the absence of local injury to the tendon or the toe, further examination is unnecessary to establish functional impairment of the tibial nerve

If the entire foot can be examined satisfactorily, further evidence may be obtained by inability to plantar-flex or adduct the foot at the ankle. These functions are accomplished, respectively, by the gastrocnemius group and the tibialis posticus which are innervated by branches of the tibial nerve arising in the proximal third of the lower leg.

INDICATIONS FOR EXPLORATION

Preoperative clinical and laboratory studies of motor, sensory, and vasomotor functions will indicate usually the degree of physiologic disruption of a peripheral nerve. However, there can be *complete physiologic loss of function* without *anatomic severance of the nerve*. This fact explains the frequency with which injured peripheral nerves regenerate spontaneously. Because of the likelihood of spontaneous regeneration, the surgeons in World War I recommended a waiting period of from six to nine months before advising exploratory operations. However, more recent investigators believe that the degenerative changes which inevitably occur in nerve ends and in the denervated muscles are progressive, and that the best results are obtained in those cases where repair is accomplished early; therefore, waiting for spontaneous regeneration is unjustifiable.

The policy presently followed in this clinic is to explore *all* cases of peripheral nerve palsies, complete or incomplete, unless there has been rapid, progressive improvement of symptoms. If the nerve has been severed, valuable time has been saved by early repair. If the nerve is anatomically intact, freeing it from the surrounding scar tissue will usually hasten recovery and seldom retard it. It is believed that exploration of any major nerve trunk under proper conditions can be accomplished without risk to life or to function.

The policy of radical exploration, however, should always be combined with one of conservative treatment once the nerve is exposed. Unless actual anatomical division can be demonstrated, or unless the intrinsic scar is so dense that no motor or sensory impulses can be demonstrated to pass through the scar, only complete neurolysis should be done. If a nerve thus treated fails to show evidence of regeneration within two months, re-exploration is done, and if there are still no sensory impulses passing through the scarred area, resection with end-to-end suture is undertaken.

All cases of suture—or neurolysis for that matter—should be observed carefully week by week for evidence of new functional activity. If at any time satisfactory progress seems to have stopped, reexploration should be recommended.

The value of the Tinel's sign in diagnosis has been discredited by many observers because of the frequency with which percussion impulses can be transmitted through scarred soft tissue to a distant neuroma. If the percussing stroke is heavy, no doubt the jarring will invalidate it. The

wounds. The only common nerve injury apt to be missed, if careful study of toe motions is made, is the posterior tibial nerve in fractures and shrapnel wounds of the lower third of the leg. In this lesion only the intrinsic musculature of the foot is paralyzed, and very little disability results except that which may follow anesthesia of the sole of the foot.

Common Peroneal Nerve. Figure 16-4 illustrates the position of the great toe which cannot be reproduced if there is interruption of the common peroneal nerve or its deep branch proximal to the middle of the lower leg. The terminal phalanx is extended on the proximal and the latter is extended on the first metatarsal. This action can be produced only with good contraction on the extensor hallucis longus whose tendon can readily be palpated over the dorsum of the first metatarsophalangeal joint. It is supplied by the deep branch of the common peroneal nerve in the proximal third of the lower leg. If this position of the toe cannot be maintained in the absence of local injury to the tendon or the toe, further examination is unnecessary to establish functional impairment of the peroneal nerve.

Fig 16-4 Test for peroneal nerve function. Great toe is held in dorsiflexion at the interphalangeal and metatarsophalangeal joints. The terminal phalanx is extended on the proximal and the latter is extended on the first metatarsal. The ability to assume this position indicates that the function of the tibial nerve proximal to the middle of the lower leg has not been impaired. (From Spurling, R. G, and Matson, D. D Army M. Bull., 75:75, 1944)

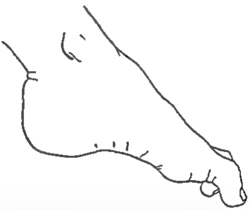


Fig 16-5 Test for tibial nerve function. Great toe is held in plantar-flexion at the interphalangeal and metatarsophalangeal joints The ability to maintain the toe in this position indicates that the function of the tibial nerve proximal to the middle of the lower leg has not been impaired. (From Spurling, R. G., and Matson, D. D. Army M. Bull, 75:76, 1944)

If the entire foot can be examined satisfactorily, further evidence may be obtained by inability to dorsiflex or evert the foot at the ankle (foot-drop). These functions are accomplished respectively by the tibialis anticus and the peroneus longus and peroneus brevis which are innervated by branches of the common peroneal nerve arising in the proximal third of the lower leg.

Tibial Nerve. Figure 16-5 illustrates position of the great toe which cannot be reproduced if there is interruption of tibial nerve function proximal to the middle of the lower leg. The terminal phalanx of the toe is flexed on the proximal and the latter is flexed on the first metatarsal. This action can be produced only with good contraction of the flexor

joints of the extremity to shorten the course of the nerve. In most major nerve trunks, gaps of from 3 to 4 inches can be overcome by correct dissection and positioning.

It has often been said that extensive dissection of a nerve trunk destroys too much of the blood supply for satisfactory regeneration to occur. This assumption is probably incorrect, as I have on several occasions stripped 18 inches of the central end of a major nerve trunk with good functional recovery. The longitudinal blood supply is probably the most important, and if this is undamaged by the dissection, no ischemic degeneration should occur.

When motor branches must be sacrificed in order that tension may be relieved, due consideration should be given to the handicap produced and the possibility of combating it at a later date by appropriate tendon transplantations.

After the greatest mobilization by dissection has been made, the joints of the extremity should be placed in the optimum position to shorten the course of the nerve. The joints should be flexed only enough to accomplish this objective.

2. *Careful hemostasis* is especially important in peripheral nerve surgery. A wet field, with the inevitable swelling that accompanies it, is incompatible with consistently good results. It should be unnecessary to say that a tourniquet is seldom necessary or justifiable in operations upon peripheral nerves unless there is an associated lesion of one of the major blood vessels.

After trimming the central stump until normal appearing nerve bundles are seen and the distal stump until well formed bundles of Schwann cell tubes are evident, brisk bleeding from the stumps may occur. This is best controlled by placing, and holding in place with gentle pressure, a thin strip of gelfoam over each cut end. After three or four minutes the foam can be gently removed with a stream of normal saline without again opening the bleeding points.

CHEMOTHERAPY. Since most nerve injuries occur in compounded wounds the possibility of infection is always a serious one. Chemotherapy is no substitute for adequate surgery—any compound wound should be thoroughly and completely débrided. As an additional safety factor, such patients should have the benefit of modern chemotherapy—penicillin or sulfadiazine or both. Adequate blood levels should be maintained for from 3 to 10 days postoperatively.

Selection of the Time for Definitive Nerve Surgery. In contrast to the progressive intraneural pathologic changes which dictate in large part the upper level of the optimum time for nerve repair, the factors which contraindicate primary nerve surgery in an injured extremity are entirely technical and mechanical:

1. The suture of a divided peripheral nerve at the time of wound débridement is not feasible by any technical standards, nor is it compatible with the surgical principles of preservation of life or extremity or of the prevention of infection, which must be dominant at this time;

2. It is often not possible for the surgeon to estimate the intraneural damage to nerve segments adjacent to the point of severance;

sign should be elicited by very gentle tapping with the finger tips along the course of the nerve, always working from below the lesion upward. At the point where tingling in the peripheral distribution is produced, functioning sensory fibers are believed to be present. The Tinel's sign when performed properly is a valuable one, especially in following the progress of regeneration after suture.

The Anesthetic. Since much valuable information can be obtained by electrical stimulation of the exposed nerve trunks, operations should be performed whenever possible under procaine infiltration. Once the direct stimulation data have been obtained, a shift to general anesthesia is frequently desirable, particularly if the procedure is prolonged by the necessity for wide dissection and extensive mobilization of contiguous joints. It is surprising though how frequently two and three hour operations can be accomplished with but little discomfort to the patient under local infiltration and direct nerve block of the proximal segment.

Electrical Stimulation of the Exposed Nerves. Electrical stimulation of the exposed nerve trunk is valuable in determining its anatomic continuity. Galvanic, faradic, or sinusoidal current provides a satisfactory stimulus. The minimal current is that which will produce a visible contracture of muscle fibers when the electrodes are applied directly to them. The current should be increased four or fine times above this minimal level before deciding that there are no functioning fibers passing through the involved segment

If stimulation proximal to the scarred area causes contraction of muscles normally innervated by the nerve distal to the scar, it may be assumed that there is still anatomic and physiologic continuity of the motor fibers.

If stimulation of the nerve proximal to the scar fails to elicit motor responses even with five times the minimal stimulus, it may be assumed that anatomic continuity is lost, provided the nerve has been liberated from its extrinsic scar prior to the test.

If the operation is conducted under local anesthesia and no procaine has been infiltrated into the proximal segment of nerve, information of great value can be obtained from the sensory responses. Stimulation of the scar or neuroma is always painful, more so than stimulation of normal nerve above the scar. Stimulation distal to the scar without sensory response indicates disruption of the afferent fibers unless the amount of current is excessive and overflows into the neuroma, thus confusing the interpretation.

Sensory responses to electrical stimulation are valuable in cases of reexploration after suture. Not infrequently, physiologically active sensory fibers can be demonstrated traversing the suture line before any motor fibers have reached their appropriate end plates

General Principles of Nerve Repair. No discussion of technical details of peripheral nerve surgery would be complete without first reemphasizing the importance of two cardinal principles: 1, freedom from tension, 2, perfect hemostasis(5, 7, 11, 13).

1. When large gaps are to be overcome, *tension* is by far the most difficult problem. Yet, to compromise with this principle means inevitable failure. It can be accomplished in many cases only by extensive dissection of the proximal and distal ends of the severed nerve and by positioning the

The second major change in the distal trunk, which takes the form of tubule atrophy, can with some qualifications be readily associated with the lapse of time after wounding, although it is difficult to correlate exactly the fibrotic changes first described with the passage of time. Progressive tubule atrophy in uncomplicated nerve injuries may vary in severity from case to case, but it remains a stable measure of the duration of distal segment deterioration unless it is even more adversely influenced by the factors of ischemia or traction. The normal maturation of regenerating nerve fibers depends to a large extent upon the number and volume of these tubular spaces. Although the upper limit of potential functional regeneration cannot be fixed with certainty, it is a warrantable assumption, on the basis of this evidence, that it is within the three-month period following injury.

SURGICAL TECHNIC

While planning the operation it is important to anticipate the possible extent to which it may be necessary to carry the dissection both proximally and distally. The whole extent of these areas should be included in the prepared and draped operative field. It is always the tendency of the inexperienced operators to attempt repair through a short incision; the mark of the expert operator is adequate skin incision.

Fig 16-6 Incision from exploration of median nerve in arm and forearm (From Seletz, E. J. Neurosurg., 3:135, 1946)

Placing of the incision is of utmost importance(8). It must not cross skin folds about joints for the resultant scar often impairs function. Figures 16-6 through 16-21 show the most useful incisions for the more common nerve lesions.

3. *Selective section of nerve ends prior to suture is impossible* unless a *large nerve gap is arbitrarily established;*

4. Mobilization and transplantation procedures essential for restoring the nerve gap and delimiting suture line tension are surgically unsound for fear of infection;

5. While in cleanly lacerated or in small penetrating wounds immediate nerve suture might be carried out by flexion of contiguous joints, the results in cases in which nerve gap has been overcome by flexion alone are likely to be prejudiced both by joint contractures and by the adverse effect of postoperative stretch upon the suture line. Moreover, this method may not be applicable if the point of suture is distant from an articulating surface;

6. Finally, the epineurium of a freshly divided nerve is thin and friable, *and lacks the tensile strength to hold sutures.*

In spite of this array of arguments, surgical opinion is by no means unanimously in favor of delayed nerve suture. On the other hand, the case for this plan has been well stated by Seddon(7): "... the delayed operation (in war wounds of peripheral nerves) converts the suture from a procedure carried out under restriction into one in which the surgeon is free to do as he wishes. At Oxford, all the primary sutures compare unfavorably with early secondary sutures, and if I had the misfortune to suffer a nerve injury myself I would prefer the secondary operation."

The practice of delaying operation to wait for evidence of spontaneous regeneration *is indefensible. In the interim irreversible* pathologic changes *occur in the form of progressive degenerative changes in the distal nerve* trunk, nerve endings, and distal articulations, which impair and eventually invalidate the functional results of axonal regeneration. Furthermore, there is considerable evidence that these alterations impair nerve regeneration adversely in direct ratio to the length of time between the injury and the attempt at definitive suture.

A description of the entire gamut of changes in all the tissues of a denervated extremity is too complex a task to undertake here(6), and the emphasis will be directed to the most important alteration, which occurs in the distal nerve segment(7, 12, 13).

The first evidence of changes leading eventually to deterioration of the distal nerve trunk throughout its entire extent is a slight fibrotic thickening of the epineurium, which occurs between 15 and 25 days *after severance of the nerve. Within this period the epineurium first attains the tensile strength which facilitates* nerve suture As time passes, the distal trunk exhibits two types of tissue reaction. The first type may be summed up in a single word—fibrosis. The epineurium becomes thicker and more dense. Collagenous tissue spreads diffusely in the interfascicular spaces. The normal cross-section area of the fascicles is diminished as the result of an enveloping perineural fibrosis which may progress to practical obliteration of the fascicular masses. Although the entire cross area of the distal nerve trunk diminishes in size, the atrophy of fascicles is compensated for by a relatively greater ratio of *interfascicular fibrosis. Simultaneously*, with the *fibrotic* changes described, there *may be seen an endoneural* fibrosis, which at times almost replaces the attenuated groups of atrophic tubules.

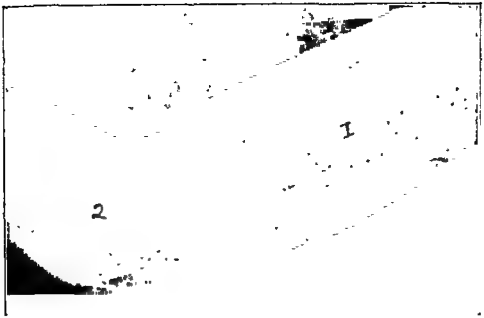


Fig. 16-9. Incision for exposure of the ulnar nerve. Incision No. 1 was used for neurorrhaphy, after transplantation of nerve was performed through incision No. 2. (From Seletz, E. J. Neurosurg., 3:135, 1946.)

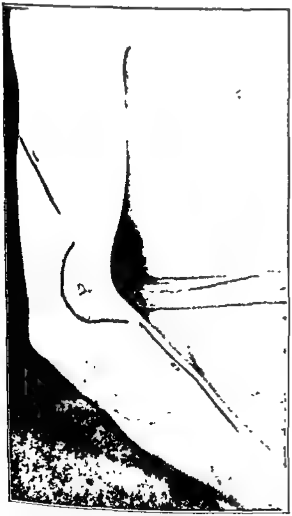


Fig. 16-10. Incision for exposure of the radial nerve. 1, in the arm, 2, lateral to the cubital fossa; 3, in the forearm. (From Seletz, E. J. Neurosurg., 3:135, 1946.)

Fig. 16-11. Exploration of the brachial plexus. Transverse axillary incision. (From Seletz, E. J. Neurosurg., 3:135, 1946.)

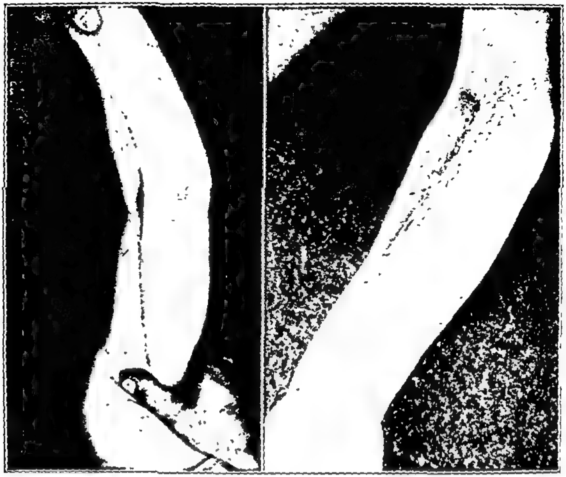


Fig. 16-7 Left, traction scar resulting from an incision perpendicular to flexion crease at the cubital fossa. Right, extensive incision crossing the flexion crease at the cubital fossa. (From Seletz, E J Neurosurg, 3 135, 1946.)

Fig. 16-8. Incision from exposure of the ulnar nerve in the arm, at the ulnar notch, and in the forearm. (From Seletz, E. J. Neurosurg, 3 135, 1946.)

and distal stumps just touch each other. Too much tension on this stitch causes wrinkling of the tubes—too little leaves an undesirable dead space.

Fig 16-13 Exploration of the brachial plexus Supraclavicular incision for exposure of the brachial plexus in the neck. (From Seletz, E. J. Neurosurg., 3:135, 1946.)

Fig. 16-14. Exploration of the brachial plexus. Infraclavicular incision for exposure of the brachial plexus beneath the pectoralis major muscle. (From Seletz, E. J. Neurosurg., 3:135, 1946.)

After the sling stitch is placed and tied, a series of fine interrupted sutures of 0.003 inch tantalum wire is placed in the perineurium. Tantalum wire sutures welded to fine curved needles are now available (Figs. 16-22 through 16-26).

In making an end-to-end suture, it is desirable that no twisting of the proximal or distal trunks should occur. To prevent rotation, an orientation suture should be placed in the perineurium above and below the lesion before dissection of the ends has been attempted. Such an identification suture serves another useful purpose. Roentgenograms should be taken when the operation is completed so that a record is made of the relative position of the wire identification sutures and those at the suture line. Follow-up roentgenograms will give invaluable information when suture line disruption is suspected.

To replace a carefully made nerve anastomosis into a bed of scar tissue has always been conceded to be undesirable (10, 11). Surgeons have resorted to many materials—fat pads, fascial sheets, preserved membranes, and excised segments of arteries and veins—in an effort to eliminate or diminish

Choice of suture material for the repair of nerve injuries is important. It must be *inert*, and it must possess *good tensile strength.*

Fine tantalum wire and human hair have been known to be practically inert when buried in human tissues. Both are of approximately the same caliber but tantalum wire has far greater tensile strength. Fine black silk causes excessive tissue reactions; catgut is totally unsuitable as it produces intense tissue reaction.

Fig. 16-12. Traction scar resulting from an incision perpendicular to flexion crease at the axilla. (From Seletz, E J Neurosurg. 3 135, 1946)

The usual method of end-to-end repair of large nerves with only a series of sutures in the perineurium is open to certain criticisms. Correct apposition at the periphery of the union can be maintained, but the centrally placed tubular structures may separate, particularly if there is tension upon the loose tissues of the perineurium A sling (traction) stitch placed through the center of the upper and lower trunks and tied with just enough tension so that the tubular structures meet, appears to be the answer to these criticisms. The chief objection to the sling stitch in the past has been the inflammatory reaction occurring around the suture material. With fine tantalum wire this objection has been removed. When the sling stitch is tied, great care must be exercised so that the cuff surfaces of the proximal

the extrinsic scar. Most of these materials have been abandoned because the resulting fibrosis was seldom diminished and often increased by the would-be protective substance. A cuff of thin tantalum foil wrapped around the nerve prevents scar tissue from infiltrating into the suture line. It has been clearly demonstrated that a noninflammatory membrane resembling peritoneum forms on either side of the foil.

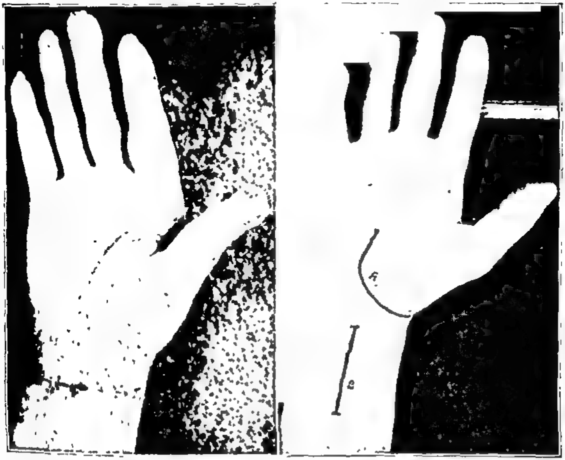


Fig 16-17. Left, incision for exposure of the median and ulnar nerves at the wrist. Right, combined incision for exposing the median nerve in the hand and in the forearm (From Seletz, E. J. Neurosurg., 3:135, 1946.)

In applying the cuff, a number of precautions must be observed. *First,* the foil must be smooth and unbroken, or fibrous tissue will grow through every little tear and fix the nerve firmly to the surrounding scar. The foil may be annealed by wrapping around an obturator, inserting the obturator with its covering of foil into the sheath, and heating the whole assembly in a flame until the sheath just begins to glow We have used a large ventricular needle with its stylet as an obturator for this purpose. Thus treated, the foil maintains a firm spring curl and is much easier to apply to the nerve without wrinkling. *Second,* the cuff is held in place by two circular ties of 00000 plain catgut. The foil cuff should be just long enough to protect the suture line—about an inch on either side.

It is very important that the central stump of the severed nerve should be trimmed until normal appearing nerve bundles appear. Likewise, the distal stump should be trimmed until well formed bundles of Schwann

Fig 16-15. Traction scar resulting from erroneously planned infraclavicular incision crossing the anterior axillary fold. (From Seletz, E J Neurosurg., 3:135, 1946.)

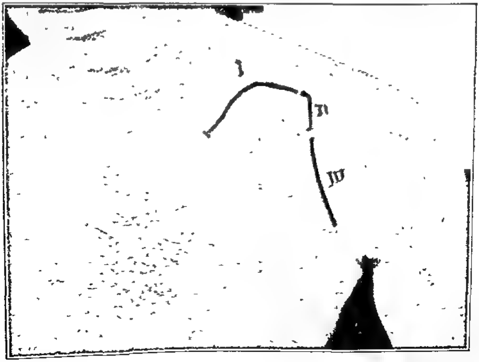


Fig. 16-16. Exploration of the brachial plexus Transclavicular approach for exposure of the brachial plexus above, below, and beneath the clavicle. (From Seletz, E J Neurosurg, 3:135, 1946)

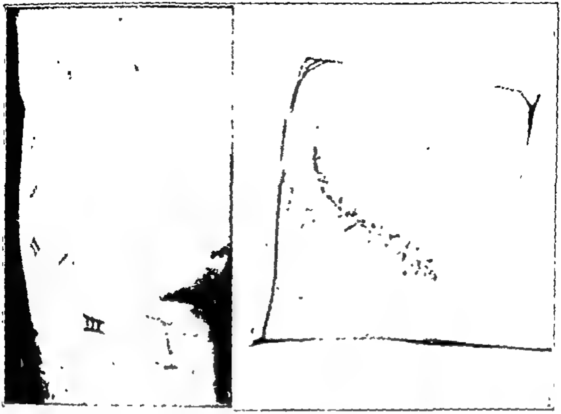


Fig. 16-19 Left, incision of Stookey for exploration of the sciatic nerve from its exit at the sciatic notch to the gluteal fold. Right, incision for exposure of the sciatic nerve at the gluteal fold. (From Seletz, E.: J. Neurosurg. 3:135, 1946.)

Fig. 16-20 Incision for exposure of the tibial nerve in the leg. (From Seletz, E.: J. Neurosurg. 3:135, 1946.)

Fig. 16-18 Left, incision for exploring the tibial and peroneal nerves in the region of the popliteal fossa. Right, traction scar resulting from an incision perpendicular to the flexion crease at the popliteal fossa. (From Seletz, E J Neurosurg., 3:135, 1946)

Fig. 16-22. Drawing illustrating the steps in repair of an ulnar nerve in the lower third of the forearm. Left, the ulnar nerve with a large neuroma at the site of the previous operative repair. Top right, the neuroma has been resected and the sling stitch placed. Note orientation sutures of black silk. Bottom right, the repair with interrupted sutures of tantalum wire has been completed. (From Spurling, R. G.: S. Clin. North America 1491, Dec. 1943.)

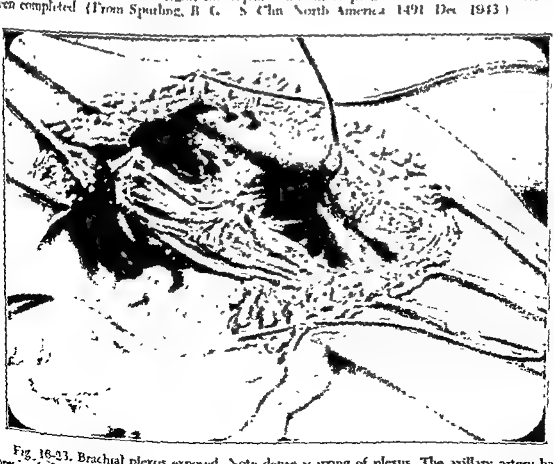


Fig. 16-23. Brachial plexus exposed. Note dense scarring of plexus. The axillary artery had [illegible]ted. (From Spurling, R. G.: J. Neurosurg., 1 140, 1944.)

cell tubes are evident. There can be no compromise with these trimming procedures, for unless the anastomosis is made of tissue free of scar, the operation is doomed to failure.

In many instances, it will be found necessary to transplant the ends of the severed nerve to a new anatomical environment in order that tension on the suture line may be reduced. This is particularly true of the ulnar and radial nerves where transplantation is relatively simple and effectual.

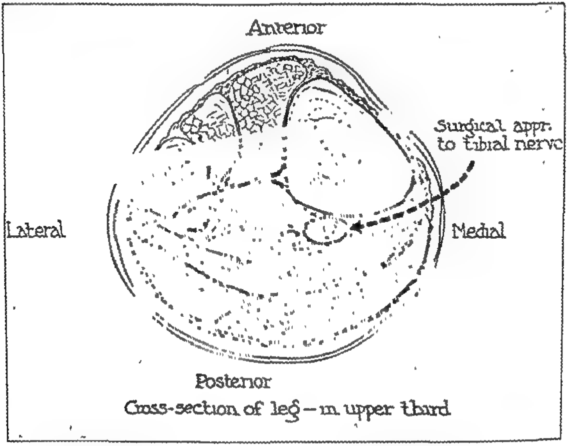


Fig 16-21 Cross section of the leg in its upper third showing the relationships of the tibial nerve, and the surgical approach (From Seletz, E. J Neurosurg, 3 135, 1946.)

Incomplete division of a nerve is not infrequently found. If the anatomically intact part contains functioning fibers, then every effort should be made to save this part while repairing the divided part. It is often possible to separate the nerve into two parts by longitudinal dissection, making an end-to-end suture of the severed portion and leaving the intact portion coiled free in the tissues

In certain cases where it is impossible to do a primary end-to-end suture without tension, the two-stage method may be effective. In the first stage, the neuroma and the pseudoneuroma are tied tightly together with 0.005 inch tantalum wire after the contiguous joints have been placed in extreme flexion. The extremity is immobilized in a cast, and after two weeks, gradual extension of the joints is started, thus automatically stretching the nerve. When full extension is reached, the wound is reexplored, the neuromas excised, and again tension is relieved by flexing the joints, after which an end-to-end suture is performed in t

Fig. 16-25 *Left*, severance of the outer half of the sciatic nerve by bayonet. Note the large neuroma formed just above the scar. *Right*, the neuroma and scar are excised. Note that the medial half of the nerve is intact. (From Spurling, R. G.: S. Clin. North America, 1491, Dec. 1943.)

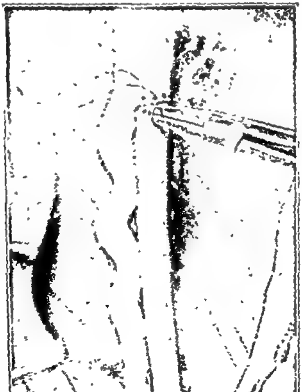
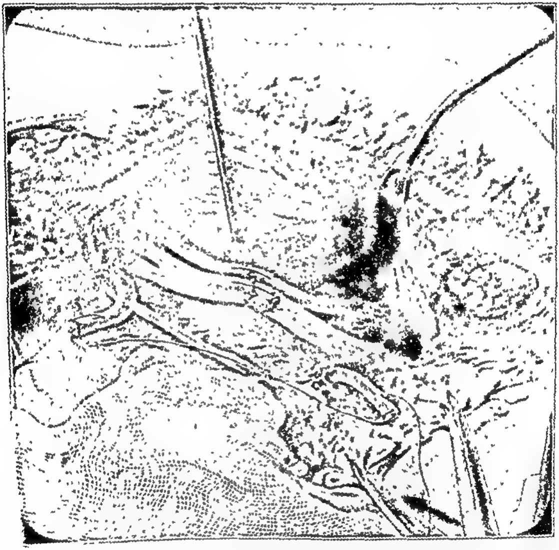


Fig. 16-26 An end-to-end suture of the outer half of the nerve is accomplished after extensive dissection of the proximal and distal ends and 90-degree flexion of the knee. (From Spurling, R. G.: S. Clin. North America, 1491, Dec. 1943.)

Plaster casts for immobilizing the extremity are almost always necessary after nerve anastomosis. Many otherwise perfect operations are ruined by improper application of restraining casts—too frequently this part of the procedure is relegated to technical personnel. The position of the extremity must be maintained rigidly while the cast is being applied or else undue stretch may be placed on the newly approximated nerve ends, and immediate suture line disruption will occur. This is particularly true with high sciatic nerve sutures. To obtain relaxation here, it is often neces-



[illegible] After resecting scar end-to-end sutures of the musculocutaneous and median [illegible] with sutures of fine tantalum wire. The sling stitch in the ulnar nerve has [illegible] From Spurling, R. G J Neurosurg, 1 141, 1944.)

group there may be excellent regeneration, yet the extremity remains functionally poor. Great improvement can be expected in patients who will cooperate fully in a reeducational program. They must learn to make use of muscles whose motor connections with the brain have been mixed up—just as the patient whose facial nerve has been anastomosed with the hypoglossal must learn to move his facial musculature through the hypoglossal pathways in the brain stem and cerebrum.

Sensory regeneration in a mixed nerve is less of a problem, for the anesthetized areas may function usefully although the central connections are bizarre.

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The cast may be bivalved after one week, after which massage of soft tissues and heat applications may be employed. The joints are gradually extended after the third week, and full extension is completed by the end of the sixth week. The condition of the suture line should be carefully evaluated by roentgenograms when extension is completed, and if suture line disruption is suspected the anastomotic area should be reexplored promptly.

AFTERCARE

The operation is but a single phase of the treatment of an extremity paralyzed as the result of a peripheral nerve injury. Obviously, an extremity will be functionally useless, however satisfactory the nerve repair and subsequent regeneration may be, if temporarily denervated muscles are permitted to become irreversibly atrophied or fibrosed, or if the joints of the wrist, hand, ankle, or toes are "frozen" beyond repair. For the best results it is, therefore, essential that physical therapy be employed both before and after operation.

Recent experiments and clinical studies(1, 2, 3, 5) have indicated that daily galvanic stimulation of denervated muscles will prevent atrophy and retard fibrosis, and this measure was therefore employed as a routine in all cases, beginning with 15 brisk contractions daily and progressing gradually to 30 contractions. When casts were used for postoperative immobilization, windows were cut over the bellies of the paralyzed muscle groups and galvanic stimulation was begun the day after operation. Other measures included massage, active and passive motion, and the use of dry and moist heat as indicated. Particularly careful attention was given to the active and passive motion of small joints. Fixation by splints was kept at a minimum, detailed instruction of the patients in respect to the care of their own joints being considered more important than mechanical methods of fixation

RESULTS

Some 8,000 cases of nerve suture have been listed in the Army's Peripheral Nerve Registry. Most of these cases have had careful followup studies for periods ranging from six months to two years. A recent primary analysis of data indicates that in 85 per cent of cases there is unmistakable evidence of regeneration. Just how complete the ultimate functional recovery will be cannot yet be determined. The data are presently being assembled under the direction of Dr. Barnes Woodall. Publication of the detailed analysis of the long term results is anticipated within the near future

Apparently all peripheral nerves, regardless of their location, possess the same ability to regenerate, providing the surgical treatment is adequate and the operation performed during the optimal period post injury However, there is inevitable mixing of fibers at the suture line no matter how meticulous the repair. In nerves, predominantly motor, which supply muscles concerned with gross movements (radial and musculocutaneous) functional recovery is more perfect than in nerves supplying muscles concerned with fine, precision movements (ulnar and median). In the latter

posterior auricular, and occipital arteries. Free anastomosis prevails and the liberal blood supply is conducive to considerable hemorrhage from wounds of small size. Local digital pressure at the wound edges will control bleeding until more definite treatment is available.

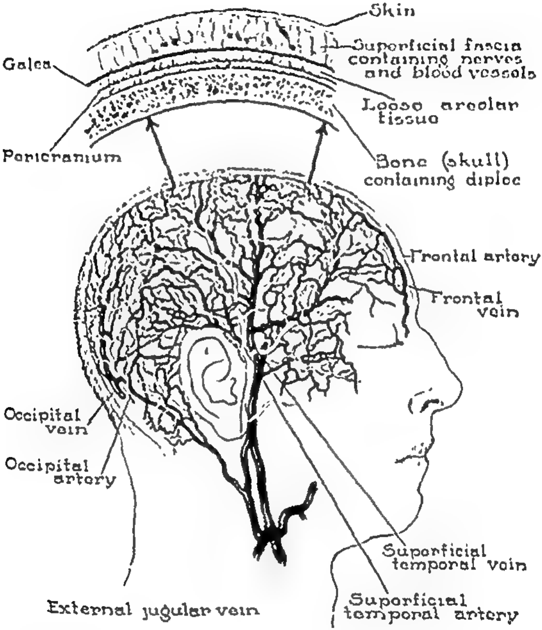


Fig. 17-1 Anatomy of scalp and skull.

Generally, the venous return parallels the arterial tree. The temporal and posterior auricular veins drain into the internal jugular vein, while the occipital veins drain into the deep cervical veins. The supraorbital and frontal veins, however, drain into the cavernous sinus via the ophthalmic veins. The scalp veins also communicate with the intracranial venous system (parasagittal and lateral sinuses) through the diploic veins of the skull, through emissary veins which pass from the scalp through the skull to the intracranial sinuses. The venous flow is reversed when there is a high degree of intracranial pressure. These connections must be kept in mind to avoid unnecessary hemorrhage at operation, but more particu-

17

SCALP, CRANIUM, AND BRAIN

Howard A. Brown and Howard C. Naffziger

Space does not permit inclusion of all the technical details which are required by experienced neurologic surgeons. It is hoped that sufficient data are presented to be of assistance to general surgeons who are confronted with the problems of diagnosis, trauma, and infections.

ANATOMIC CONSIDERATIONS

The principal function of the skull is to afford protection to its contents rather than, as in the bones of the extremities, to serve as a site for muscular attachments. The scalp consists of five distinct layers: the skin, superficial fascia, galea aponeurotica, loose areolar layer, and pericranium (Fig. 17-1).

The skin consists of a heavy epithelial layer with numerous sebaceous glands and is united to the fibrous superficial fascia beneath it. Heavy fibrous trabeculae filled with nodulated fat hold these two layers in firm approximation and form a framework which contains the blood vessels, lymphatics, and nerves. The nature of these structures allows little or no motion in these layers.

The galea aponeurotica is the tendinous expansion of the occipitofrontalis muscle with which it is continuous anteriorly and posteriorly. Laterally it blends with the temporal fascia forming attachments to the zygomatic arches, thus producing a fibrous encasement for the entire skull.

Beneath the galea is a loose areolar tissue which has very little attachment to the pericranium beneath, or to the galea above, and consequently allows a considerable freedom of movement of the scalp upon the pericranium and skull. This mobility will also permit closure of a scalp wound after the loss of a good deal of tissue. This loose areolar layer is also of importance in scalp infections for it permits rapid spread of the infection which may require prompt surgical drainage.

The pericranium, or periosteal layer, forms a smooth covering of the skull which is easily removable except at the suture lines where it is quite adherent. Accumulations of blood or fluid beneath the pericranium are often sharply demarcated at the suture lines if the membrane is not ruptured. The bone-forming powers of the pericranium are extremely limited, even in younger individuals.

Blood Supply. Arrangement of the blood supply and its drainage is to be taken into account in the placement of incisions, in plastic repairs, and in the control of bleeding. The arterial supply of the frontal portion of the scalp is derived from the internal carotid artery through the ophthalmic artery and frontal and supraorbital vessels. The external carotid artery supplies the remainder of the scalp through the superficial temporal,

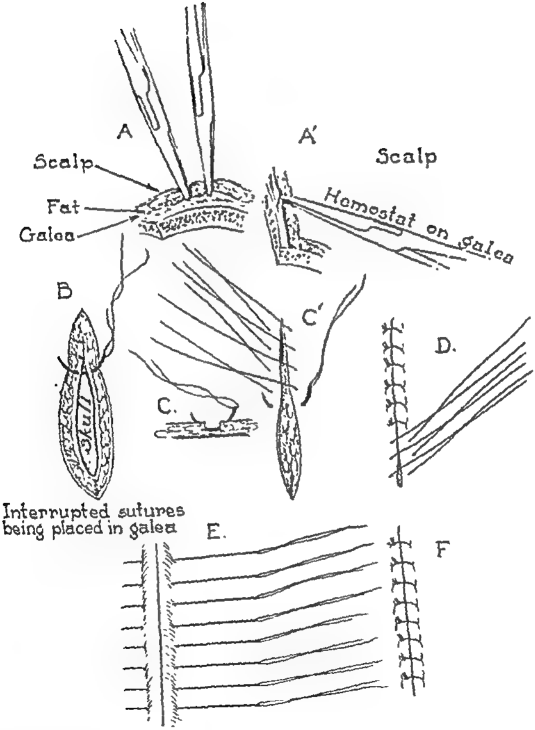


Fig 17-2. A and A', hemostasis obtained by clamps turning galea against scalp B, C and D, proper method of scalp closure in two layers Superficial closure with curved needles. E and F, superficial closure with straight needles

larly because of the part they may play in the spread of superficial infection into the intracranial spaces.

Nerve Supply. The sensory function of the anterior portion of the scalp is supplied through branches of the fifth cranial nerve and the posterior portion through the cervical plexus ($C^{2,3}$) by way of the great occipital nerve.

The motor supply to the occipitofrontalis muscle is from the facial nerve while the temporal muscles are supplied by the motor divisions of the fifth cranial nerve.

Lymphatics. The lymphatics of the scalp are numerous and drain posteriorly into the suboccipital glands. The postparietal drainage is into the glands behind the ear and over the mastoid, while those in the anterior portion of the parietal region and brow drain into the parotid and submaxillary lymphatics.

The Cranium. The cranium entirely surrounds the brain but allows egress of the spinal cord, cranial nerves, and vessels through various foramina.

The vault consists of relatively thick bone, except in the temporal region, and is made up of an outer and inner table separated by diploë. Venous channels lie within the diploe and vary considerably in size and number although there is a relative symmetry between the two sides. Where the bone is thin, as in the temporal region, the diploe diminish or disappear completely The overlying temporal muscle and fascia, as well as the zygoma, add strength and protection to this region.

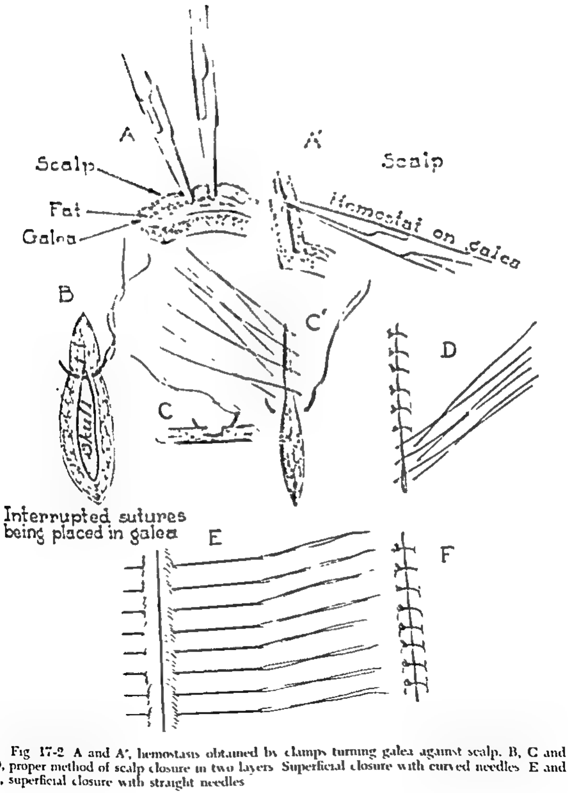
The heavy dura lines the interior of the skull, and on its outer surface lies the middle meningeal artery which grooves the skull. It often tunnels the bone in the lower temporal region so that fractures may lead to rupture of it and extradural hemorrhage. Some areas of the base of the skull are relatively thin. The weaker areas are the orbital plates, the sphenoidal and ethmoid cells, and the lowermost portions of the middle and posterior fossae. The petrous bone is weakened by the auditory canal, air cells, middle ear cavities, and canals for the seventh and eighth nerves.

INJURIES

Contusions of the Scalp. Contusions of the scalp without open lacerations result in local swelling and hematoma formation. Aspiration or incision is rarely necessary and increases the danger of infection. Absorption is frequently very slow. Palpation of hematomas often gives a false impression of an underlying depressed fracture which can be settled by x-ray studies

Lacerations of the Scalp. Lacerations which do not penetrate the full thickness of the scalp require sutures only if a pressure dressing is not sufficient to control bleeding. Lacerations which tend to gape are closed with the fewest sutures which will produce approximation. Fine silk or cotton buried sutures for the galea and separate ones for skin approximation control bleeding and cause the least scar (Fig. 17-2).

Preparation of the wound and surrounding scalp by adequate shaving is necessary before any repair is undertaken The wound may be packed by sterile dressings during this procedure. With men it is advisable to clip the hair far enough back so that no hair may reach the wound when it is



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Closure is in two layers, the galea being closed first, followed by careful approximation of the scalp, using interrupted sutures of fine silk or cotton (Fig. 17-2). With loss of tissue various extensions of the scalp wound may be required to mobilize the scalp sufficiently to permit approximation of tissues without tension (Fig. 17-4). Tension sutures in the scalp must be avoided as they will impair circulation. Ordinarily, if the skin can be approximated with fine silk sutures in the galea, there will not be too much tension to interfere with wound healing.

Early repair and thorough cleansing of the wound makes drainage rarely necessary. Emphasis should be placed on secure dressings. Proper bandaging to prevent their displacement is too often neglected. Stockinette caps or head pieces are simple and efficient.

Secondary skin grafts or plastic closures may be necessary when other measures are inadequate. These require considerable delay for granulation, preparation of the bed and graft, particularly if pedicle grafts are used.

Fractures of the Skull. Simple linear fractures of the skull present no operative problem. However, when they extend into contaminated areas, e.g., to the nasal sinuses, or permit outside communication as in fractures of the base of the skull through the petrous bone manifested by bleeding from the ear, the possibility of intracranial infection exists. The ingress of air through the dural rent (pneumocele) may be an added complication.

Cerebrospinal rhinorrhea and pneumoceles most often occur in association with fractures involving the cribriform plates and orbital roofs. The immediate use of antibiotics and early repair of the torn dura by means of fascial grafts are required. An osteoplastic craniotomy is in order to close the dura by suture or with fascial graft (Fig. 17-23).

Nonpenetrating depressed fractures may occur with or without scalp laceration. The presence and extent of any depressed fracture should be determined by x-ray studies. The treatment of shock, if present, must take precedence until movement of the patient or the surgical repair of the head injury will not jeopardize the patient's recovery. In the presence of an open wound the time for elevation of a simple depression will depend upon the associated conditions. The assessment of other serious injuries must not be overlooked. Associated cervical, clavicular, and thoracic injuries are not infrequent.

Nonpenetrating depressed fractures in the absence of an open wound become emergencies in the presence of intracranial complications. Such damage as may have occurred to the brain is due to the trauma and not to the continuance of the depression. However, constant changes in brain volume and intracranial pressure occur physiologically. For this reason restoration of a smooth contour on the inner surface of the skull by elevation of the depression is desirable.

If no scalp wound overlies the depression, a scalp incision is fashioned to adequately expose the area of depression with sufficient margin to allow for some enlargement of the defect if necessary. A curved flap type of incision is usually most satisfactory. Lacerations over depressions should be enlarged to allow sufficient scalp retraction for complete exposure of the depression (Fig. 17-5).

brushed toward it. With women the hair may be braided away from the wound. Many surgeons prefer to clip all the hair, particularly where extension of the incision might become necessary. Meticulous care in shaving, particularly at the edges of the wound, allows for better repair and decreases the hazard of *infection.*

Extensive wounds and those with loss of tissue require shaving and preparation of the scalp over a wide area, as the repair is a major surgical procedure. Devitalized tissue is trimmed off, foreign particles removed, the wound mechanically cleaned and irrigated, and a fresh set of instruments used for the repair.

If an anesthetic is required, local anesthesia is preferable. One half of one per cent procaine with two to four drops of 1:1,000 adrenalin solution is satisfactory. The injection is made through the scalp and between it and the bone in sufficient amount to raise a welt. Fifteen or 20 minutes are required to secure the full effect. The injections are made at a distance of 2 or 3 cm. from the wound (Fig. 17-3).

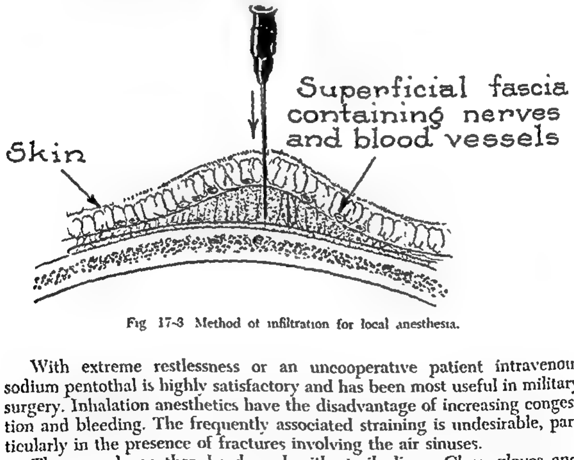

Fig 17-3 Method of infiltration for local anesthesia.

With extreme restlessness or an uncooperative patient intravenous sodium pentothal is highly satisfactory and has been most useful in military surgery. Inhalation anesthetics have the disadvantage of increasing congestion and bleeding. The frequently associated straining is undesirable, particularly in the presence of fractures involving the air sinuses.

The wound can then be draped with sterile linen. Clean gloves and gown are provided for the operator. With a scalpel, ragged edges of the scalp are trimmed back to normal tissue, attempting to cut at right angle to the scalp surface to insure good closure Contaminated instruments are discarded and bleeders controlled by hemostats applied to the galeal edges.

Large quantities of Ringer's solution at 104° in bulb syringes are used to wash out foreign material and debris Inspection of the wound with removal of hair or any indriven foreign material accompanies the irrigation.

Depressed fragments are often comminuted and wedged together tightly. The inner table is usually more extensively fractured than the outer table and tongue-like projections of the inner table may extend well beyond the limits of fracture in the outer table. This fact is of importance in elevating the fragments which cannot be lifted directly upward but may

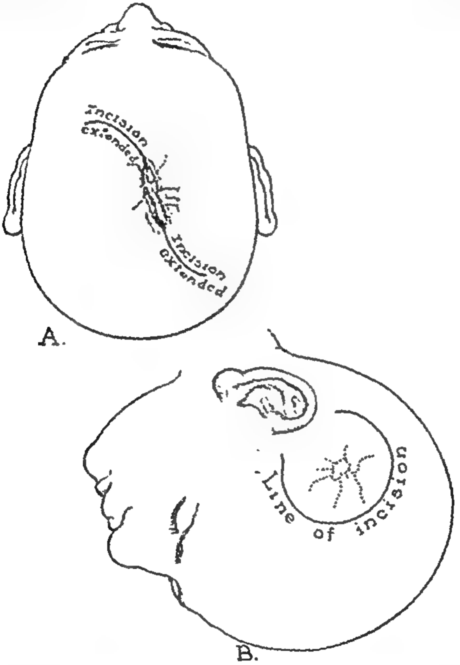

Fig. 17-5. A, extension of scalp wound to obtain adequate exposure of depressed fracture. B, curved flap type incision to expose depressed fracture

have to be slid out on an angle, so that it is dangerous and inadvisable to pry up depressed fragments blindly through a small bone opening. Hemorrhage from dura or brain may follow such a procedure and cannot be controlled due to inadequate exposure Also, lacerations of the dura and brain, and penetrating fragments of bone, may be overlooked by such a procedure and may lead to late complications such as infection or excessive brain scarring and convulsions.

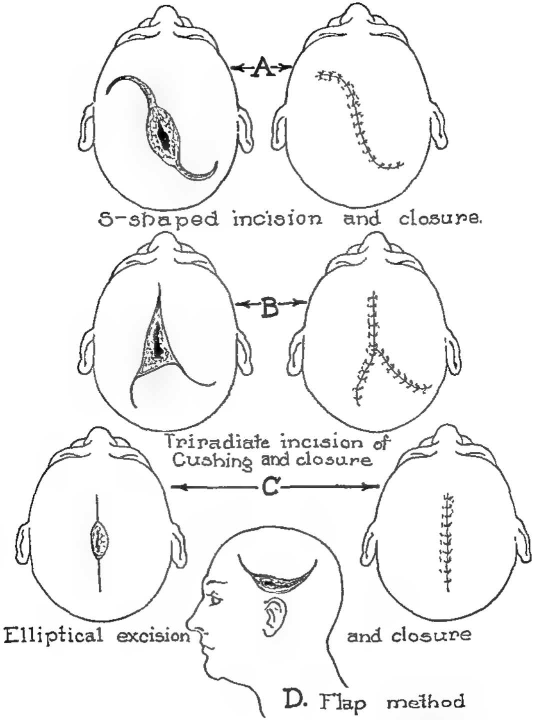

Fig. 17-4. Various incisions used in scalp closure following scalp lacerations

Two methods are usually employed, either piecemeal removal of fragments or bloc removal. Piecemeal removal of fragments is best accomplished by making a small bone opening at the margin of the depression with rongeurs (Fig. 17-6). This brings the dura into view and increases the safety of the remaining bone removal. If the fragments are wedged in tightly it may be necessary to rongeur more bone away at the margins to allow the fragments to be slid out without force. By these means excessive hemorrhage and further damage to underlying dura and brain may be avoided. If, however, inspection of the dura after removal of fragments reveals it to be tense, discolored, or without pulsation, it may be necessary to open it to evacuate subdural hemorrhage or spinal fluid accumulations which are causing brain compression. This is contraindicated in infected wounds.

Bloc removal of bone requires four or more bur holes around the site of fracture and these are connected by rongeurs or gigli saw cuts, allowing the entire area of depression and immediately surrounding bone to be removed in one piece. A larger bone defect results from this procedure and there is some question as to the need for this type of removal excepting in badly soiled cases (Fig. 17-7).

Penetrating Wounds of the Brain. Penetrating injuries include many depressed fractures, stab wounds, and wounds from projectiles. Surgical effort is directed toward minimizing the brain damage, evacuating blood clots, removal of foreign material, prevention of meningitis, septic encephalitis and brain abscess, and lessening the likelihood of sequellae. Operative treatment is urgent but should not be undertaken except when facilities and personnel are available for the most thorough care. Experience has shown that transportation of the patient to appropriate surroundings yields better results than immediate but incomplete procedures.

Supportive measures, restoration of blood and fluids, antibiotics, maintenance of free airways with free supply of oxygen, control of hemorrhage, and sterile dressings are immediate needs. Neurologic examination and detailed x-rays to determine the extent of bone damage and the presence and position of foreign objects and bone fragments are in order.

When the dura has been penetrated and the brain beneath has suffered injury, it is necessary to enlarge the dural opening for a better view of the injured cortex.

The devitalized brain tissue is removed by gentle suction, associated with frequent irrigation, using warm (104° F.) Ringer's solution (Fig. 17-8). Control of hemorrhage in the brain presents a special problem and special methods of controlling bleeding have been devised.

Meticulous attention to hemostasis is of major importance. Metal clips for large vessels, electrocoagulation, and fibrin foam saturated with thrombin solution are used (Fig 17-9). Fibrin foam and gelfoam have largely replaced the use of small pieces of muscle, but muscle and fascia are useful in suturing tears of the dural sinuses.

Indriven bone fragments or retained foreign bodies may be seen in x-ray plates and should be removed. Shell fragments may be too extensive or too far from the local brain wound to permit their removal without damaging surrounding brain and obviously this is inadvisable.

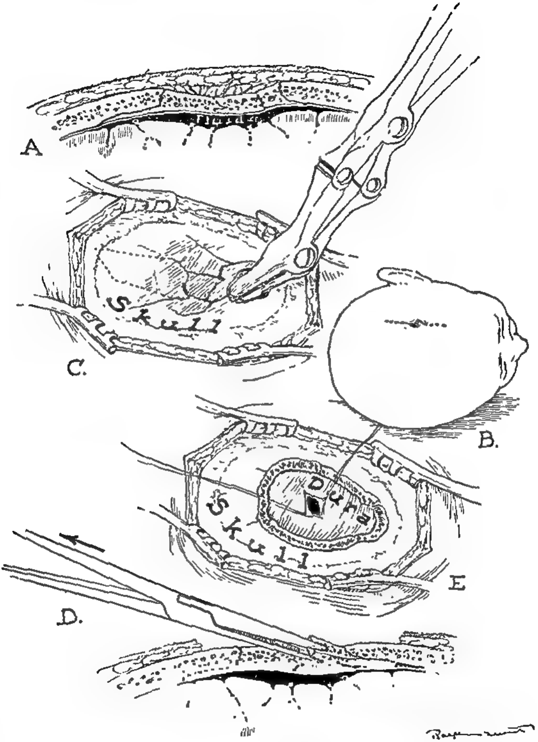

Fig. 17-6 Piecemeal removal of depressed fragments A, comminuted depressed fracture. B, extension of wound to obtain adequate exposure C, rongeuring edge of depression to loosen fragments. D, removal of fragments E, fragments removed Dura opened to evacuate clot.

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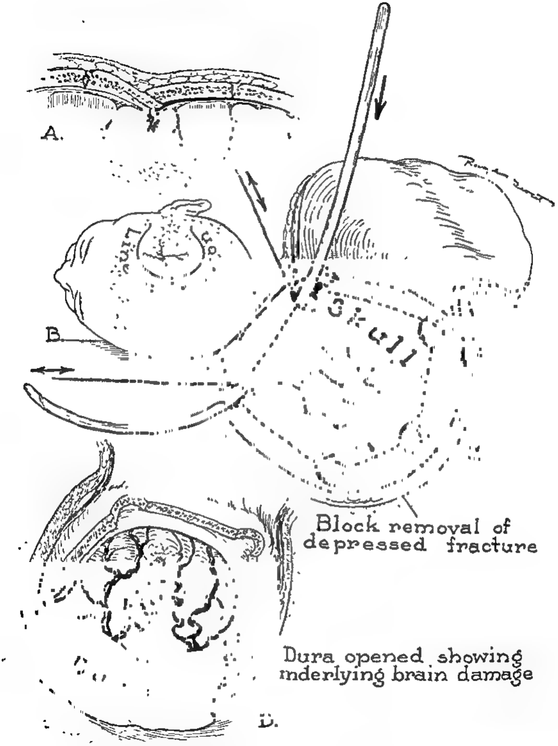


Fig. 17-7 Bloc removal of depressed fracture A, comminuted depressed fracture. B, curved scalp incision for exposure. C, saw cuts surrounding fracture for bloc removal D, dura opened showing underlying brain damage

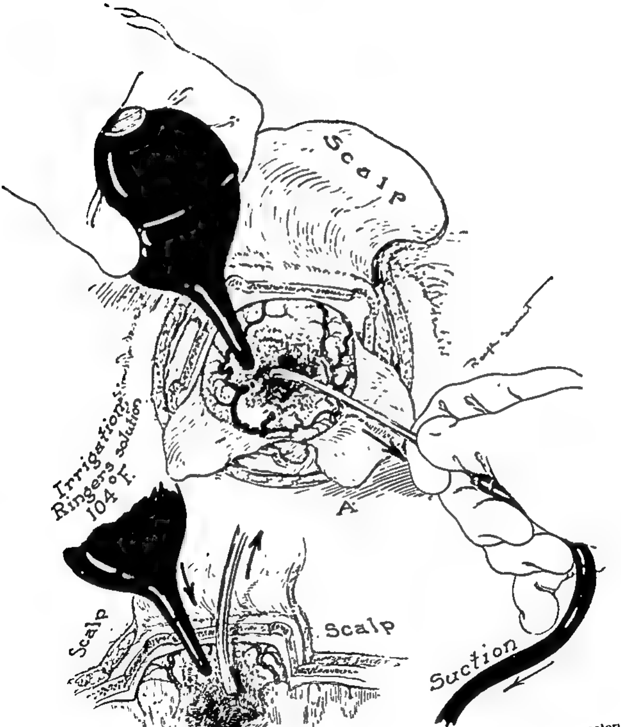


Fig 17-8 Removal of damaged brain and indriven fragments of bone and foreign material

Bone fragments may be found by gently probing the depths with a blunt probe and grasping the fragments with long thin forceps. Retained bone fragments cause a much higher degree of infection and abscess formation than do metallic foreign bodies. Projectile fragments are usually very hot upon entrance into the cranial cavity and are relatively clean.

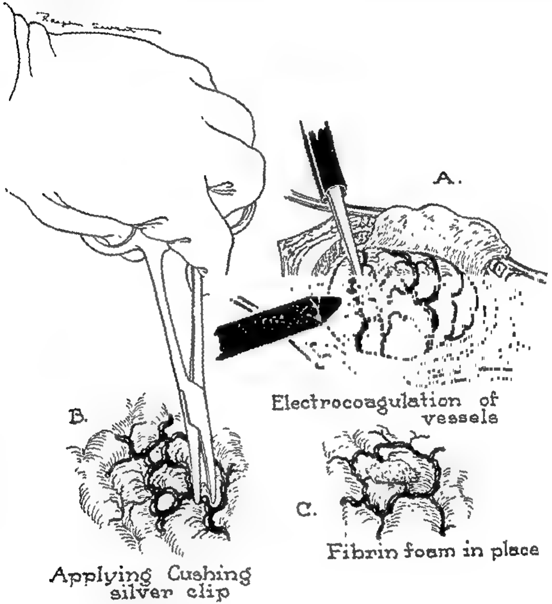


Fig 17-9 Methods of obtaining hemostasis in the brain.

After a thorough débridement of the brain wound, the dura should be tightly closed with silk sutures to prevent brain herniation with scar formation, and the entrance of infection. If the brain is tense, spinal puncture may be done to lessen the intracranial tension. Often the dura is badly lacerated or some portion destroyed, preventing adequate repair and requiring some type of graft. The temporal fascia, or fascia lata from the thigh, may be used for this purpose (Fig. 17-10). Of foreign membranes used to cover dural defects fibrin film has been satisfactory.

Fibrin film is an absorbable membrane easily workable when soaked in saline solution, and which produces little or no adherence to the pia mater and brain. It is replaced by a new, dura-like membrane.

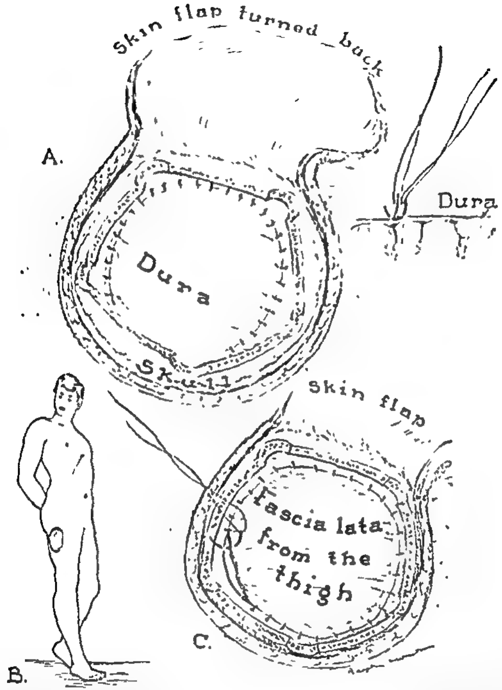


Fig 17-10. Closure of damaged dura A. complete closure with interrupted silk sutures where little or no tissue has been destroyed. B and C, closure by graft from fascia lata where considerable dura has been lost.

Defects of the Skull. Bone fragments, depending upon the presence or absence of contamination, may be left in place to avoid a defect (Fig. 17-11). Bur openings in areas uncovered by hair and other small defects are satisfactorily covered by screen mesh of stainless steel or tantalum. For large defects auto bone grafts from the ilium or tibia may be used. Recently tantalum plates have been popular.

When wounds are contaminated the early use of any foreign material leads often to faulty healing and infection. Several months after clean healing the defect may be covered. Tantalum causes little reaction and is readily workable.

Several methods are utilized in preparation and fixation of these plates. Those which are done as a primary procedure are accomplished by cutting out a *piece of tantalum plate (0.015 in. thickness) with heavy scissors* and shaping it to the size of the defect. The curve and contour are obtained by beating the metal on a hard wooden block which has been prepared with suitable depressions to allow for the shaping process. By this means it is possible to shape even the difficult contours about the brow and *supraorbital region, and here, a model cut from a soft lead plate is of* great assistance in cutting and shaping the tantalum plate. The plate may

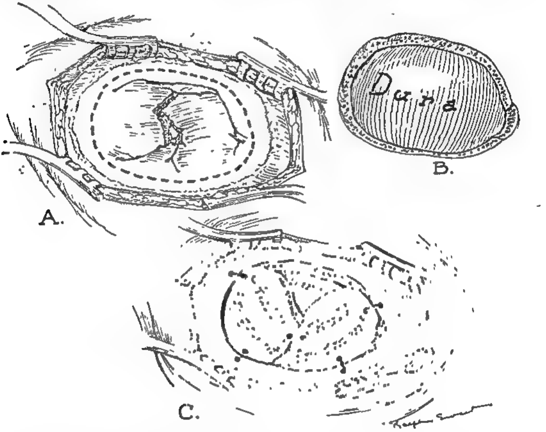


Fig. 17-11 Closure of bone defect with bone fragments A, comminuted depressed fragments before elevation. B, bone defect following removal of fragments C, partial closure of defect with fragments wired in position

be used as an onlay, or the bone margins may be cut down slightly to allow it to fit flush with the surrounding skull. Fixation is accomplished by small tantalum screws, or by small bits of tantalum driven into the bone at the margins much as a glazier point holds a window pane in place (Fig. 17-12).

When a secondary repair is contemplated, models of the defect may be made on the scalp with dental wax or other appropriate material, and plates are fashioned by swedging the metal under pressure to obtain an accurate contour.

After insertion of the plate hemostasis should be meticulous and a dressing with uniform mild pressure is used Occasional aspiration of fluid collections beneath the scalp may be required.

Middle Meningeal Hemorrhage. Middle meningeal hemorrhage is a surgical emergency. The classical history of unconsciousness following head

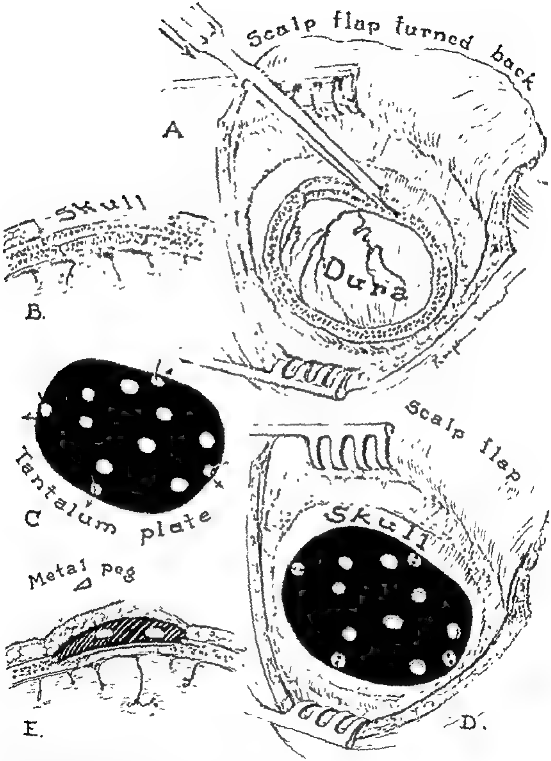


Fig 17-12 Repair of skull defect with tantalum plate A, removal of small ledge of bone allowing plate to lie flush with skull B, transverse view of the same, C, tantalum plate with perforations D, plate *in* place held by tantalum screws E, transverse view showing fixation with tantalum points rather than screws

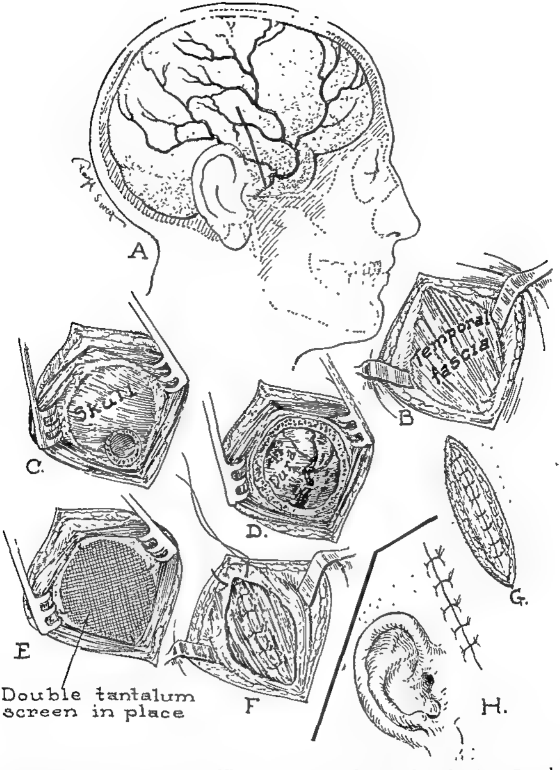


Fig 17-13. Operative steps in middle meningeal hemorrhage. A, line of incision B, scalp incised C, temporal muscle retracted, bur opening in skull showing extradural clot D, bone opening enlarged Clot largely removed Clip on meningeal artery. E, stainless steel screen covering bone defect F and G, closure of temporal fascia, galea and scalp in separate layers H, skin closures.

injury, succeeded by a return to consciousness and then deepening stupor, is by no means invariable. Gradually increasing stupor with intracranial pressure is usual with hemorrhage from this or other intracranial sources. X-ray evidence of fracture through the squamous portion of the temporal bone suggests the possibility of injury to the middle meningeal vessels. Bur openings in this area or over the vault (Fig. 17-13) may be required to locate the bleeding (subdural hematoma; see below).

The surgical approach best adapted to evacuation of the clot is through a subtemporal bone opening, beneath a straight incision, extending upward and backward from the zygoma (Fig. 17-13). A preliminary bur opening may help in determining whether the major portion of the clot is high or low, and the enlargement of the bone opening can be made accordingly. The clot must be evacuated carefully by irrigation and suction, and bleeders in the dura may be controlled by electrocoagulation, silver clips, or fibrin foam and thrombin solution. Too vigorous an attempt to remove particles of the clot will result in bleeding from many sources on the dura which are difficult to control It is unnecessary to attempt to remove every bit of the clot from the dural surface for this produces innumerable tiny bleeding points. Small remnants of clot do not cause untoward symptomatology. The brain is relaxed and pulsates freely following the evacuation of the clot, and there is usually a gap between dura and bone as the result of the brain compression which makes careful hemostasis essential. Some surgeons prefer to drain the extradural space with a soft rubber drain for 24 hours, but it is not necessary if the wound is dry.

In the presence of an extradural clot the dura is not opened unless by its color there is also an indication of subdural bleeding. The temporal muscle, fascia, and scalp are closed in layers with fine cotton or silk sutures.

Subdural Hematomas. While subdural bleeding is not infrequent, the development of subdural hematomas with progressive signs occurs weeks or even many months after trauma. Rupture of veins over the vault or very rarely in the posterior fossa permits the formation of a clot which encapsulates and increases in size by osmosis. The clinical signs may be those of generalized pressure only. With signs indicating some unilaterality of the lesion it must be remembered, nevertheless, that about 50 per cent of cases have bilateral bleeding. Bloody or xanthochromic fluid revealed by spinal puncture is not invariable.

Exploration should be bilateral. Under a local anesthetic bur openings are made (Fig. 17-14). Evacuation of the clot by irrigation and suction will be all that is required in 80 per cent of cases. In others a solid or recurring clot may require later osteoplastic craniotomy for removal (Fig 17-24).

In acute craniocerebral injuries which are progressing unfavorably, exploratory bur openings (Fig. 17-14) may be used as a diagnostic procedure when there are no clear signs of localized accumulations of blood. Operation is performed under local anesthesia, the patient being placed either in the prone or supine position if possible, and four small scalp incisions are outlined anteriorly and posteriorly on each side (Fig. 17-14). Self-retaining mastoid retractors hold the scalp edges apart and bur holes are placed in the skull. Some surgeons prefer a high temporal opening for preliminary exploration.

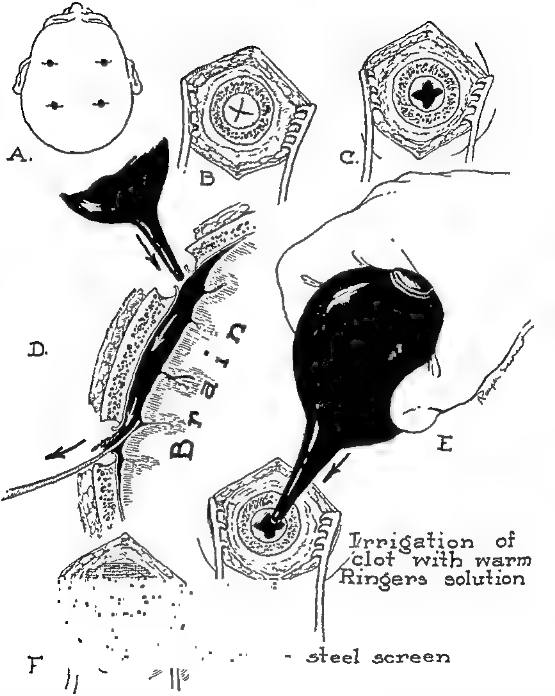


Fig 17-14 Operative steps in subdural hematoma A, location of incisions. B, bur opening through skull. Outline of dural opening C, dura opened revealing subdural hematoma sac. D and E, method of washing out contents of sac F, stainless steel screen over bone opening to prevent scalp dimpling.

The dura is then carefully opened in a stellate fashion, revealing the dark, bluish sac of the hematoma beneath. As soon as this is opened, dark brown prune-juice-like material gushes forth, containing some small clots. Irrigation with warm Ringer's solution gradually washes out further stained material but fresh bleeding is not encountered. If the brain is gently held away in the lower opening, irrigation from above will readily come out below, allowing a through-and-through washing of the sac. The brain should gradually begin to expand during the course of the irrigation, but is less responsive when the brain compression has been marked, in large hematomas or in patients of advanced age.

Occasionally, temporary improvement is followed by further signs of increased intracranial pressure and reoperation has been necessary. In these instances, an osteoplastic flap may be necessary to remove an extensive hematoma with considerable solid clot in it which simple drainage would not remove.

When the dura is opened there is very little adherence to the outer capsule of the hematoma. Its appearance is much like a slab of liver which might have been laid upon the brain surface, with its greatest thickness toward the longitudinal sinus and thinning out below, anteriorly and posteriorly.

It is not difficult to separate it from the pia to which there is no firm attachment, and the mass can be elevated gradually toward the midline. Here it must be cut away carefully, leaving a small margin to avoid damaging the longitudinal sinus with which it is often intimately associated. The dura is completely closed, the bone flap replaced, and the scalp closed in the usual manner without drainage.

Recovery is rapid unless brain injury has resulted before operative intervention is undertaken, and the majority of these patients have no permanent residual symptomatology.

Hygromas. Subdural fluid accumulations, or hygromas, occur occasionally after head trauma, and result from arachnoidal tears, allowing spinal fluid to become trapped in the subdural spaces with resultant signs of increased intracranial pressure. The clinical picture may resemble meningeal hemorrhage or have no focal or localizing aspect. The majority are discovered during an approach for suspected meningeal hemorrhage or by exploratory craniotomy openings undertaken because of progressive general signs of acute intracranial pressure without localization. The hygroma is encountered as soon as the dura is nicked and is characterized by a spurt of fluid, clear or slightly yellow in color. Evacuation of this subdural fluid results in relief of pressure and rapid recovery.

Subtemporal Decompression. Before the introduction of present methods for the localization of brain tumors and advances in the technic for their removal this operation was in common use but it is now less frequently needed for the relief of intracranial pressure. When performed for this purpose the bone removal should be a large one (Fig. 17-15) but confined to that area of the squamous portion of the temporal bone which is covered by the temporal muscle. Through a muscle splitting operation and with appropriate elevating retractors an opening of approximately 4 cm. can be

made. To obtain a decompressive effect the dura must be opened to the full extent of the bone removal.

For middle meningeal hemorrhage the approach is similar but the bone opening need only be large enough to deal with the clot and control the bleeding vessels. The dura is not opened unless some evidence of bleeding beneath it is present.

For brain swelling after injury a decompressive operation of this sort is inadequate, and evidences of dangerously high intracranial pressure are more often due to bleeding.

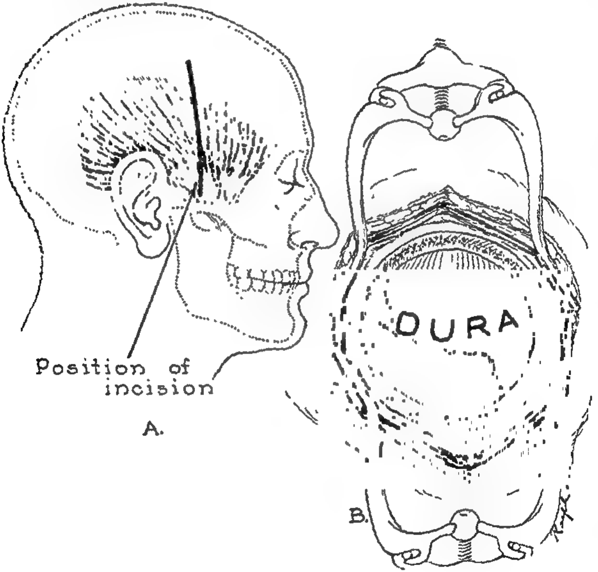


Fig. 17-15 Subtemporal decompression showing, A, site of incision and, B, extent of craniectomy.

Intracerebral Hemorrhages. Solitary intracerebral hemorrhage is not infrequent and may follow shortly after craniocerebral injury. Signs indicating its location are usually marked in addition to signs of increasing intracranial pressure. Blood in the spinal fluid may come from other brain lacerations or from rupture of it through the cortex or into a ventricle. Treatment is accomplished through a bur opening. Through a small nick in the dura a ventricular needle is used for exploration and evacuation of the blood.

Spontaneous intracerebral hemorrhage commonly is due to rupture of an aneurysm or, in persons with generalized vascular disease, to rupture of a weakened vessel. In the former it is usually associated with free subarachnoid bleeding. Since the general use of angiography the aneurysm can usually be located. A large proportion can be treated surgically. Certain ones, notably the subclinoid aneurysms of the internal carotid, require ligation of that artery. An increasing number of the small berry aneurysms can be reached. In some the vessels may be occluded with a clip and in others of the saccular type the neck may be clipped without occluding the vessels.

Solitary intracerebral hemorrhage, when due to a ruptured aneurysm, must be evacuated through a cortical incision or resection of sufficient size to permit a search for and treatment of the vessel. In the older age groups with vascular disease the more severe cerebral accidents are usually manifested by a hemiplegia with loss of consciousness and evidence of intracranial pressure. Such hemorrhages are approached surgically in the same way as a solitary hemorrhage after injury.

INFECTIONS

Scalp. Superficial infections of the scalp are usually localized and require only simple drainage to evacuate infected material and allow cleansing. Failure to deal with such infections soon enough may invite a spreading infection involving the loose, subgaleal space where a rapid spread ensues. An infection in this loose, areolar tissue will advance at a swift pace with excessive edema of the scalp which may be sufficient to close both eyes and cause a striking prominence of the ears as the swelling pushes them outward from the skull. Early and adequate surgical drainage is necessary, often requiring multiple incisions at dependent regions in the frontal, temporal, and occipital areas The incidence of such infections has decreased materially with the advent of chemotherapy.

Skull. Osteomyelitis of the skull may result from several sources: 1, spread from local infections of the scalp directly or through venous channels; 2, spreading infection from the accessory air sinuses or mastoid cells; 3, direct infection following compound skull fractures; 4, more rarely, from infected subpericranial hematomas without overlying scalp lacerations; and 5, hematogenous origin is rare.

The numerous venous diploe in the skull are conducive to extensive spread of the infection, and radical surgical removal of the involved bone is necessary. X-ray evidence is not positive for 7 to 10 days and the clinical picture of swelling, tenderness, and edema of the overlying scalp, coupled with the history, must make the diagnosis.

Osteomyelitis following trauma as a rule has less tendency to spread rapidly, and frequently may be relatively well localized. The infection may be confined to the outer table alone, but both tables are more often involved as well as the extradural space which may be covered with infected granulation tissue or frank pus. Further extension of the infection may traverse the dura, directly where laceration has occurred, or by venous channels if the

dura is intact. Such extensions produce subdural abscesses, meningitis, or brain abscesses (Fig. 17-16).

A fulminating type of osteomyelitis of the skull is that which arises from acute infections of the frontal sinuses and rapidly involves the frontal bone. Radical removal of all infected bone is usually necessary as well as thorough cleaning out of the frontal sinuses and perhaps exenteration of the ethmoid cells.

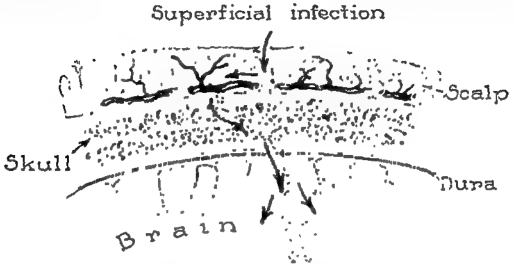


Fig. 17-16 Channels through which infection may spread from scalp to skull and intracranial spaces

Sufficient exposure must be planned to allow removal of all involved bone, and the advancing edematous edge of the scalp is helpful in determining the extent of the underlying bone involvement. The usual incisions for frontal exposure are shown in the accompanying drawings (Fig. 17-17). The scalp flaps are turned back widely and the pericranium pulled back from the bone. Many surgeons advocate careful preservation of the pericranium to encourage subsequent bone regeneration which has been reported as entirely adequate by some observers, but in our experience has not been sufficient to obviate the need for later plastic repair. Pus may be seen to exude from the infected bone which appears dirty and porous, although there may be islands of bone within an obviously infected area which have a healthy appearance.

Two methods of bone removal are employed; piecemeal or bloc removal. In piecemeal removal, a bur opening is made through the involved bone, taking care not to tear the protective dural barrier, following which the bone is removed bit by bit with rongeurs (Fig. 17-17). The limit of bone removal is determined by the extent of the infected bone. This is soft, poorly vascularized and lends little resistance to the rongeurs in contrast to normal bone which is hard and shows free bleeding edges. As normal bone is approached the dura becomes clean and the dirty granulations disappear. The bleeding from bone edges can usually be controlled by hot packs or foam and thrombin solution, for it is desirable to avoid the use of bone wax in infected cases. Thorough irrigation with warm Ringer's solution is helpful in washing away infected material following which a concentrated penicillin solution may be introduced into the wound. Formerly

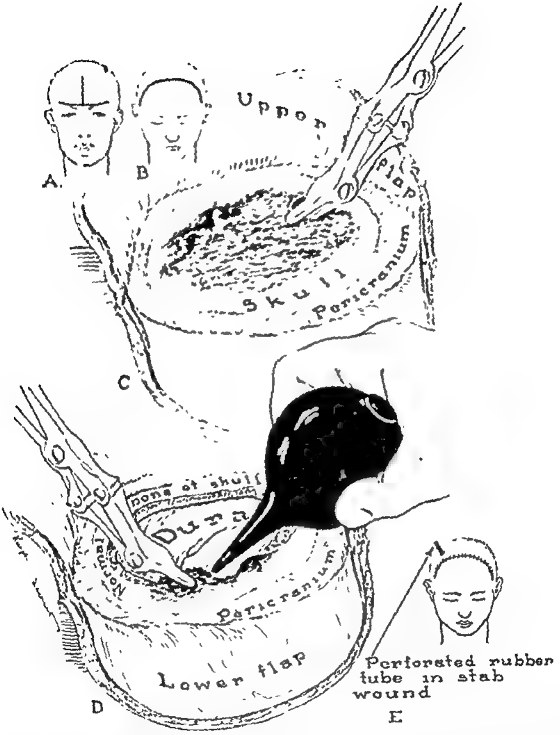


Fig. 17-17 Surgical treatment of osteomyelitis of the frontal bone A and B, types of scalp incision which may be employed C, piecemeal type of removal of infected bone. D, final stage of bone removal back to normal bone E, closed type of treatment with tube for introduction of penicillin into wound

the wound was left open and petrolatum gauze used to prevent early closure, but later the wound edges were loosely sutured to allow drainage but prevent scalp retraction and broad scars were later removed. In view of recent experiences with chemotherapy it may be possible to close such wounds primarily, inserting a small perforated rubber tube through a stab wound to allow daily introduction of penicillin. This, coupled with intensive use of sulfonamides and penicillin parenterally, and by mouth, has sufficed in some cases to allow clean wound healing in the presence of an infected field. Regardless of the method, drainage must be adequate and one must be constantly on the alert for a further spread of the infection which occurs not infrequently despite an initial radical removal of bone. Repeated operations have been necessary at times to conquer this stubborn infection.

More localized osteomyelitis such as that which may follow trauma requires less extensive surgical treatment. Infection which is superficial and involves only the outer table may be cleaned out locally with a sharp curet, osteotome, or superficial burring, followed by curettement until healthy bleeding bone is encountered. Penicillin is used locally and, depending upon the virulence and extent of the infection, the wound is drained or left open for secondary closure (Fig. 17-18).

Localized infections involving both tables require full thickness removal of the area involved and in cases of traumatic origin, one may find foreign material.

In more chronic cases of osteomyelitis of the skull, the overlying scalp shows impaired circulation and may have numerous infected sinus tracts requiring its resection and secondary skin grafting when clean granulations have covered the area of previous bone infection.

In order to minimize recurrence of infection, secondary plastic operations to repair skull defects and minimize scalp scar are not undertaken *for from 8 to 12 months after evidence of the original infection has disappeared*

Brain Abscess. Brain abscesses arise from several sources: 1, secondary to infections of the air sinuses and mastoid cells, 2, following traumatic infections, especially osteomyelitis of the skull; 3, metastatic from chest (lung abscess—bronchiectasis); and 4, blood stream origin.

Abscesses that arise from the latter two classifications are very frequently multiple Understanding of the development of a brain abscess is important with reference to its proper surgical treatment. The initial infection may be through direct extension from osteomyelitic changes in the frontal sinuses or mastoid cells or through purulent thrombophlebitic processes from these areas or infected skull. Regardless of the origin, the initial process in the brain is that of local brain softening due to a septic encephalitis which may cause rather acute symptoms. Operation at this time is inadvisable. The infection cannot be drained, and infected material is usually spread with possible production of a fatal meningitis. During this phase it appears that sulfonamides and penicillin may be of considerable value.

The second phase is the production of a reactive wall or capsule around the local infection which is all important from the standpoint of surgical

treatment. As time passes this wall becomes thicker and firmer, increasing the barrier about the abscess cavity which increases the facility of its surgical care.

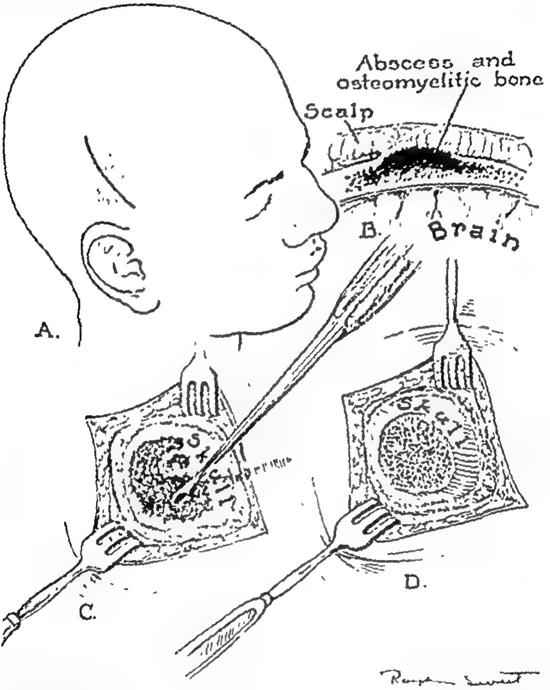


Fig 17-18 Surgical treatment of osteomyelitis involving the outer table of the skull. A, scalp incision. B, localized abscess and osteomyelitis in outer table C, curetting of infected bone. D, normal bone after removal of infected area

The time for operation depends upon the patient's general condition, signs of increasing intracranial pressure, degree of choking of disks, and the progression of neurologic findings.

Methods of surgical management are dependent upon the location of the abscess as to depth and with reference to important areas of the brain. The age of the abscess and the character of the infection are important factors in its encapsulation and the formation of its wall. Aspiration, open

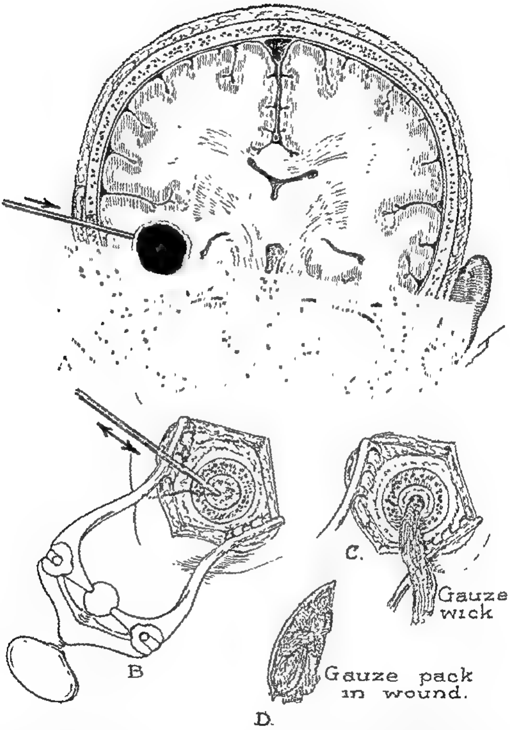


Fig. 17-19 Closed method of treatment of brain abscess A, localizing abscess with blunt needle B, needle in abscess cavity to evacuate pus and introduce penicillin C, needle tract packed with gauze wick D, wound packed open to allow subsequent aspiration of cavity.

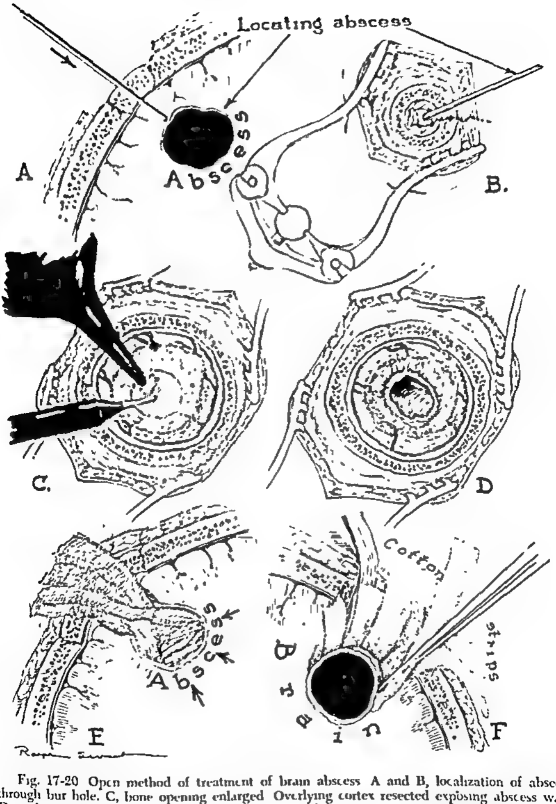


Fig. 17-20 Open method of treatment of brain abscess A and B, localization of abscess through bur hole. C, bone opening enlarged Overlying cortex resected exposing abscess wall. D, surface of abscess removed with electric knife and pus evacuated. E, abscess cavity packed with gauze allowing gradual extrusion to surface. F, method of complete extirpation of abscess by gradual separation from surrounding brain

(direct) drainage, or enucleation may be employed, depending upon these factors.

Aspiration. For deep abscesses with little resistance of the wall to the exploratory needle, aspiration of the contents is followed by the instillation of penicillin (Fig. 17-19). The introduction of 2 or 3 ml. of pantopaque permits of accurate x-ray localization and determination of the extent of the lesion and facilitates repeated aspiration if required or later excision.

Open drainage consists of the same initial approach but once the abscess is located, the bone opening is enlarged to about the size of a silver dollar. The dura is opened in a stellate manner and sealed with the electrocautery to obliterate the surrounding subarachnoid space and prevent spread of infection. The overlying cortex is removed with the electrocautery, exposing the abscess wall which is tapped to remove pus for culture as well as to decrease the tension in the abscess cavity. The abscess is then uncapped and the cavity irrigated repeatedly with constant suction in the wound. The cavity is then packed with petrolatum gauze and the superficial wound packed open as well (Fig. 17-20).

The abscess wall is gradually extruded by the brain tension from beneath and eventually can be removed completely at the surface. The wound then is allowed to close. A variation of this procedure is to suture the edges of the open capsule to the galea, marsupializing the cavity and producing an extracranial process entirely. This method is favored by many but is not applicable to deep abscesses of 3 or 4 cm. or very small ones which require aspiration

Enucleation. Abscesses that have become chronic and have a firm wall permit complete extirpation, and the operative technic is that employed for the removal of a neoplasm. Through an osteoplastic craniotomy, the dura is opened and resection of the overlying cortex permits separation of the white matter from the wall of the abscess. This procedure allows complete closure of the wound and primary healing. It is obvious that such surgical treatment is suitable when the clinical course, duration, and the cerebrospinal fluid findings give reason to believe that the infection is relatively quiescent.

TUMORS OF THE SKULL

Tumors of the skull may be primary or secondary. Of the latter the thyroid and adrenals may be the site of origin and the growths on the skull may precede other secondary growths Their slow development may warrant removal even though their metastatic character is recognized. This is in contrast to carcinomatosis with signs of widespread multiple involvement.

Osteomas of the skull may develop from the inner or outer table. The former are common on the vault and must be differentiated from the bone involvement due to an underlying meningioma On the outer table small, unsightly tumors may be simply chiseled off including the surface of the adjacent bone. Larger ones may be removed en bloc with an osteoplastic flap which is replaced at once after excision of the tumor with chisel and rasp (Fig. 17-21). Under these circumstances we have not seen a recurrence, though the replaced craniectomized portion remains viable.

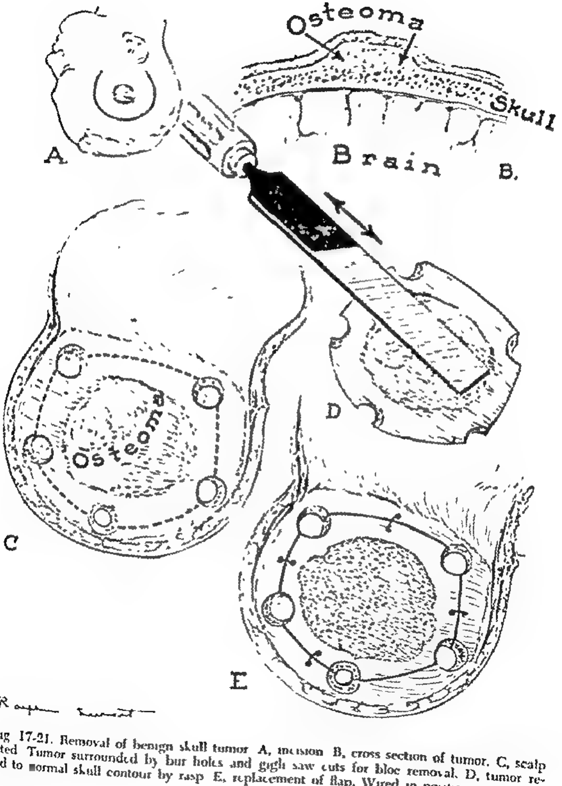


Fig 17-21. Removal of benign skull tumor A, incision B, cross section of tumor. C, scalp reflected Tumor surrounded by bur holes and gigli saw cuts for bloc removal. D, tumor removed to normal skull contour by rasp E, replacement of flap. Wired in position

Osteomas bordering the accessory nasal sinuses are rather common and a considerable literature has grown up about them. Their extirpation involves an intracranial exposure and the risk inherent in entering contaminated areas.

Hemangiomas of the skull may be single or multiple, and may gradually expand both inner and outer tables of the skull. Diagnosis is usually made by roentgenographic studies. Operative removal may be undertaken in single lesions and consists of bloc removal of bone with subsequent repair of the defect. Adequate preparation to control hemorrhage is essential before undertaking operation.

Epidermoid tumors are of congenital character, arising in the diploe of the skull and they may gradually reach such size that they require surgical removal. The operative treatment consists of bloc removal in those favorably located for such a procedure or enucleation of the contents of the cavity with careful curettement to remove all particles of the lining membrane.

Meningiomas may secondarily invade the skull, producing large surface tumors which must be dealt with in conjunction with the operative removal of the intracranial portion of the tumor.

BRAIN TUMORS

Localization. ENCEPHALOGRAPHY AND VENTRICULOGRAPHY. The surgical attack upon intracranial lesions is dependent upon accurate localization. Replacement of the cerebrospinal fluid by injection of gas (commonly air or oxygen) by the spinal route in the absence of signs of intracranial pressure is ordinarily used. In the presence of signs of intracranial pressure, particularly when evidenced by choking discs, the injection is made through bur holes and directly into the ventricles. For the former a light general anesthetic is used. The latter is performed under local anesthesia. For the details one may be referred to the monograph of Davidoff and Dyke(1). The interpretation of the roentgenograms following the air injection requires considerable experience.

ARTERIOGRAPHY. Injection of one or both carotids or the vertebral artery is useful for localization of lesions, particularly those involving the vascular system. Involvement of the major sinuses requires injection of them. Diodrast is in general a satisfactory material in 30 ml. doses of 35 per cent diodrast. The injection may be made under local or light general anesthesia. Open incision and percutaneous methods are both used. Several injections may be required to form a judgment of all portions of the vascular tree.

For purposes of localization of intracranial lesions other than primary vascular lesions encephalography or ventriculography is of much greater value. With certain neoplasms, however, knowledge of the character and source of the vascular supply may indicate the pathologic type and be of technical value at operation. In our experience the risks of angiography are greater than those of encephalography.

Operation for Brain Tumor. Intravenous fluids are administered throughout the procedure and blood for transfusion should be available for use if required.

Operative exposure above the tentorium is usually accomplished by some type of osteoplastic bone flap. Accurate localization of the intracranial lesion is imperative in order to place the operative exposure at a point which will allow the best accessibility to the tumor. Various types of scalp incisions may be employed, depending upon the area to be exposed (Fig. 17-22). Certain principles must be kept in mind in making scalp incisions. Blood supply must be adequate, and too narrow a base of the scalp flap may result in necrosis.

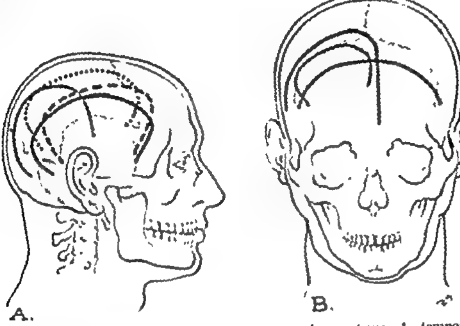


Fig. 17-22 Types of scalp incisions for intracranial operations A, temporal, parietal, occipital. B, frontal, temporal

Inclusion of the temporal muscle in the exposure allows it to be used as a hinge for the bone flap and permits its use to cover the brain under any bone decompression which may be necessary. In exposures away from the temporal region, so-called free flaps may be employed with complete removal of the bone flap and replacement at the conclusion of the operation. Cosmetic results and avoidance of unnecessary scars outside the hairline deserve attention. Scalp dimpling over bur holes may be obviated by covering the bur holes with small pieces of stainless steel screen.

The control of scalp bleeding may be accomplished by hemostats on the galea as previously described or by means of special spring clips. The scalp is usually dissected from the pericranium and temporal fascia. The latter is then incised along the course of the anticipated flap of bone. Perforator and bur openings are placed at suitable intervals and connected with gigli saw cuts. The saws are introduced with spring steel guides which protect the dura from injury while the bone is sawed. The thin temporal bone is partially rongeured and then cracked through as the flap is elevated. In frontal flaps, care must be taken to avoid entering the frontal sinuses (Fig. 17-23).

Bone bleeding is controlled by bone wax and that on the dura by electrocoagulation, muscle stamps, or fibrin foam and thrombin solution. Bone that has been invaded by tumor should be removed.

It is important not to design a flap too low in the temporal region, for

Osteomas bordering the accessory nasal sinuses are rather common and a considerable literature has grown up about them. Their extirpation involves an intracranial exposure and the risk inherent in entering contaminated areas.

Hemangiomas of the skull may be single or multiple, and may gradually expand both inner and outer tables of the skull. Diagnosis is usually made by roentgenographic studies. Operative removal may be undertaken in single lesions and consists of bloc removal of bone with subsequent repair of the defect. Adequate preparation to control hemorrhage is essential before undertaking operation.

Epidermoid tumors are of congenital character, arising in the diploë of the skull and they may gradually reach such size that they require surgical removal. The operative treatment consists of bloc removal in those favorably located for such a procedure or enucleation of the contents of the cavity with careful curettement to remove all particles of the lining membrane.

Meningiomas may secondarily invade the skull, producing large surface tumors which must be dealt with in conjunction with the operative removal of the intracranial portion of the tumor.

BRAIN TUMORS

Localization. ENCEPHALOGRAPHY AND VENTRICULOGRAPHY. The surgical attack upon intracranial lesions is dependent upon accurate localization. Replacement of the cerebrospinal fluid by injection of gas (commonly air or oxygen) by the spinal route in the absence of signs of intracranial pressure is ordinarily used In the presence of signs of intracranial pressure, particularly when evidenced by choking discs, the injection is made through bur holes and directly into the ventricles. For the former a light general anesthetic is used. The latter is performed under local anesthesia. For the details one may be referred to the monograph of Davidoff and Dyke(1). The interpretation of the roentgenograms following the air injection requires considerable experience.

ARTERIOGRAPHY. Injection of one or both carotids or the vertebral artery is useful for localization of lesions, particularly those involving the vascular system. Involvement of the major sinuses requires injection of them. Diodrast is in general a satisfactory material in 30 ml. doses of 35 per cent diodrast. The injection may be made under local or light general anesthesia. Open incision and percutaneous methods are both used. Several injections may be required to form a judgment of all portions of the vascular tree.

For purposes of localization of intracranial lesions other than primary vascular lesions encephalography or ventriculography is of much greater value. With certain neoplasms, however, knowledge of the character and source of the vascular supply may indicate the pathologic type and be of technical value at operation. In our experience the risks of angiography are greater than those of encephalography.

Operation for Brain Tumor. Intravenous fluids are administered throughout the procedure and blood for transfusion should be available for use if required.

Operative exposure above the tentorium is usually accomplished by some type of osteoplastic bone flap. Accurate localization of the intracranial lesion is imperative in order to place the operative exposure at a point which will allow the best accessibility to the tumor. Various types of scalp incisions may be employed, depending upon the area to be exposed (Fig. 17-22). Certain principles must be kept in mind in making scalp incisions. Blood supply must be adequate, and too narrow a base of the scalp flap may result in necrosis.

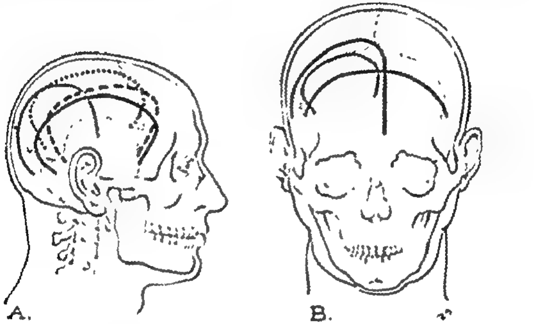


Fig. 17-22. Types of scalp incisions for intracranial operations. A, temporal, parietal, occipital. B, frontal, temporal.

Inclusion of the temporal muscle in the exposure allows it to be used as a hinge for the bone flap and permits its use to cover the brain under any bone decompression which may be necessary. In exposures away from the temporal region, so-called free flaps may be employed with complete removal of the bone flap and replacement at the conclusion of the operation. Cosmetic results and avoidance of unnecessary scars outside the hairline deserve attention. Scalp dimpling over bur holes may be obviated by covering the bur holes with small pieces of stainless steel screen.

The control of scalp bleeding may be accomplished by hemostats on the galea as previously described or by means of special spring clips. The scalp is usually dissected from the pericranium and temporal fascia. The latter is then incised along the course of the anticipated flap of bone. Perforator and bur openings are placed at suitable intervals and connected with gigli saw cuts. The saws are introduced with spring steel guides which protect the dura from injury while the bone is sawed. The thin temporal bone is partially rongeured and then cracked through as the flap is elevated. In frontal flaps, care must be taken to avoid entering the frontal sinuses (Fig. 17-23).

Bone bleeding is controlled by bone wax and that on the dura by electrocoagulation, muscle stamps, or fibrin foam and thrombin solution. Bone that has been invaded by tumor should be removed.

It is important not to design a flap too low in the temporal region, for

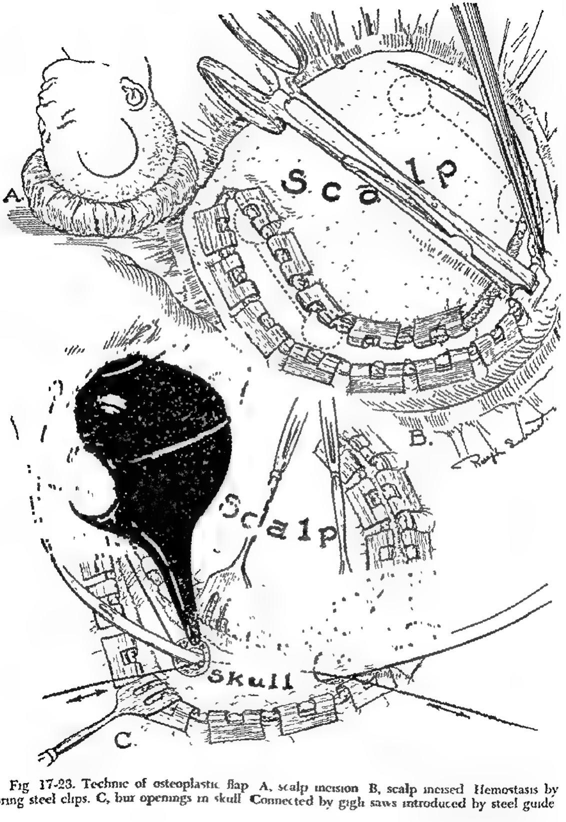


Fig 17-23. Technic of osteoplastic flap A, scalp incision B, scalp incised Hemostasis by spring steel clips. C, bur openings in skull Connected by gigli saws introduced by steel guide

profuse bleeding from a torn middle meningeal artery may be difficult to control Less trouble will be encountered by cracking the flap back at a little higher level and rongeuring out further temporal bone after the meningeal artery is in sight and within control

The dura is opened in a curved manner with a hinge at one edge, usually toward the midline (Fig 17-21) If the dura is involved by tumor, as may be the case in meningiomas, it is excised

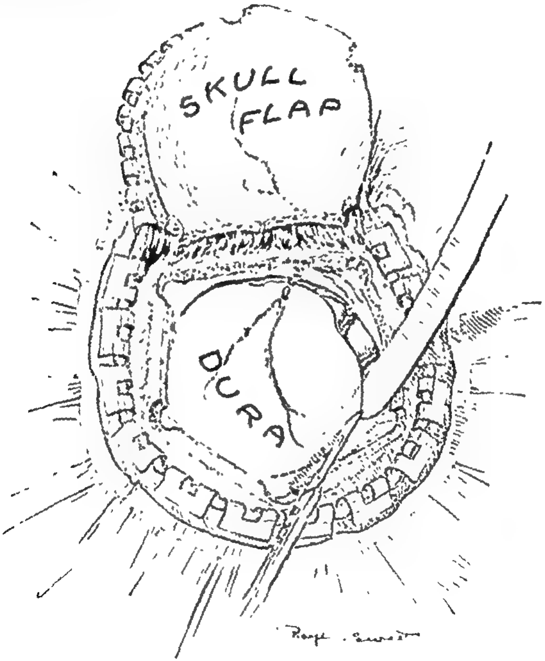


Fig 17-21 Dura opened with curved incision.

Silver clips or electrocoagulation control the meningeal artery and its branches.

The methods employed in hemostasis have been previously described under head injuries, and have the same application here.

Management of brain tissue requires extreme care in all times and in removing tumors, constant attention must be given to the protection of

Fig 17-25. Methods of tumor removal A, scalp incision B, encapsulated tumor on surface of brain. Gradual separation and removal Entering and bridging vessels clipped and divided. C, piecemeal removal of tumor with electric loop. D, partial removal of deep lying unencapsulated tumor after removal of overlying cortex

surrounding normal brain and its blood supply. Moist cotton strips are of great value in this regard.

Tumors which are encapsulated, such as meningiomas, are gradually freed from surrounding brain and all communicating vessels are clipped or coagulated and cut. Cotton strips are placed along the line of cleavage to assist in the dissection and to protect surrounding normal brain (Fig. 17-25B). Such tumors may be removed in one piece, but if too large for this procedure, the central portion may be removed piecemeal with the electric loop and the capsule gradually collapsed to allow enucleation (Fig. 17-25C). Firm attachments to the region of the large venous sinuses in the dura must be left intact to avoid serious and complicating hemorrhage.

Cystic tumors may be collapsed by aspiration or evacuation of the fluid content following which the capsule can be gradually freed and removed.

Invasive tumors of the glioma group, or those with poorly defined margins, usually recur despite radical measures of removal. A small margin of adjacent brain may be removed with the tumor if this is in an area where it will not result in damage of important brain function (Fig. 17-25D).

Deep lying tumors must be approached by resection of an overlying bloc of cortex to permit their removal. The use of the finger in gently separating deep masses is sometimes justified and allows one to feel vessel communications which can be clipped or coagulated, thus avoiding unnecessary bleeding (Fig. 17-26). Soft growths may be removed in part by means of the suction apparatus.

Fibrin foam and thrombin solution are of great value in controlling deep venous oozing but arterial flow must be stemmed by electrocoagulation or clips.

The dura is closed tightly with interrupted silk or cotton sutures, except in the subtemporal region when a decompression to relieve high intracranial tension is desired. The bone flap may be held in place by two fine wire or silk sutures, placed through tiny drill holes (Fig. 17-27). The temporal muscle, fascia, galea, and scalp are then closed in layers with interrupted sutures of fine silk or cotton and a firm protective dressing is applied.

Tumors which lie below the tentorium are approached through a suboccipital craniectomy. The sitting position is usually favored as reducing the vascularity of the tissues and lessening intracranial pressure. In this position the possibility of opening large venous channels and permitting air embolism is a special danger. Preliminary tapping of the lateral ventricles to reduce intracranial pressure is usual. Several incisions are employed, depending upon whether a unilateral or bilateral exposure may be required (Fig. 17-22). For either bilateral or unilateral exposure, the suboccipital muscles are incised just below their attachments to the skull, leaving a small fringe to allow suturing during closure of the wound. They are stripped from the bone with a periosteal elevator, following which a bur opening is made in the bone and enlarged by rongeurs, the extent depending upon the exposure desired (Fig. 17-28). The unilateral exposure is used for well localized tumors such as acoustic neuromas, or to expose cranial nerves for section as in tic douloureux, glossopharyngeal tic, and Ménière's syndrome.

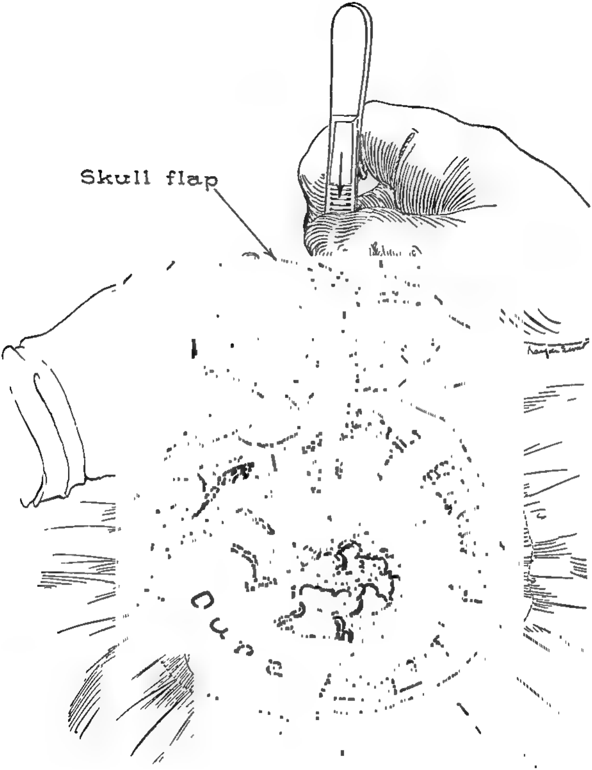


Fig 17-26 Enucleation of tumor

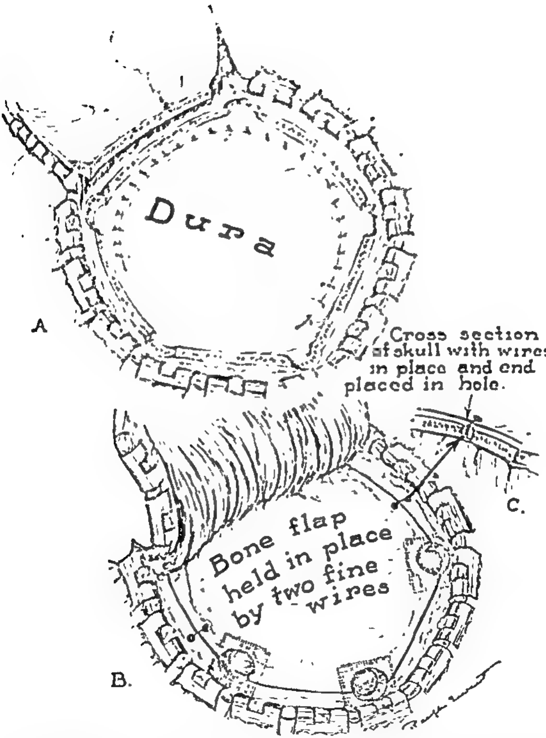


Fig 17-27 A, closure of dura B, replacement of flap Held by wire C, stainless steel screen covering bur holes

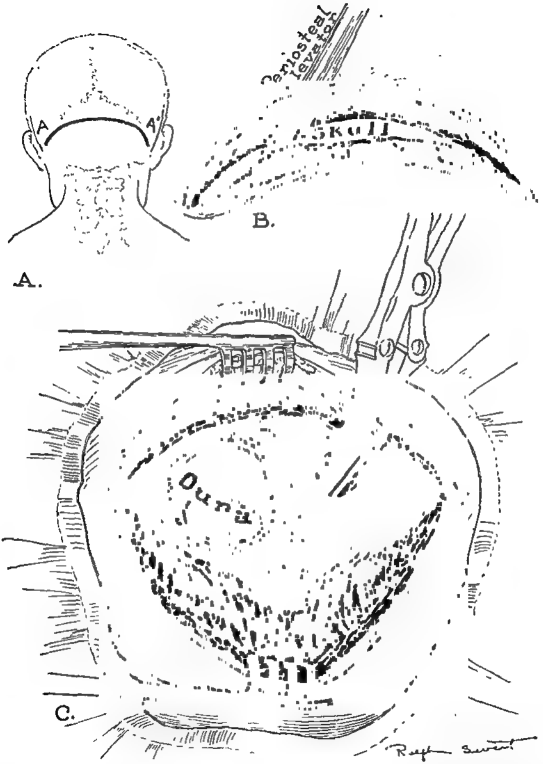


Fig. 17-28. A, exposure of posterior fossa Transverse incision for bilateral exposure B, scalp, fascia and muscles incised C, subperiosteal separation of muscles. Enlargement of bur openings

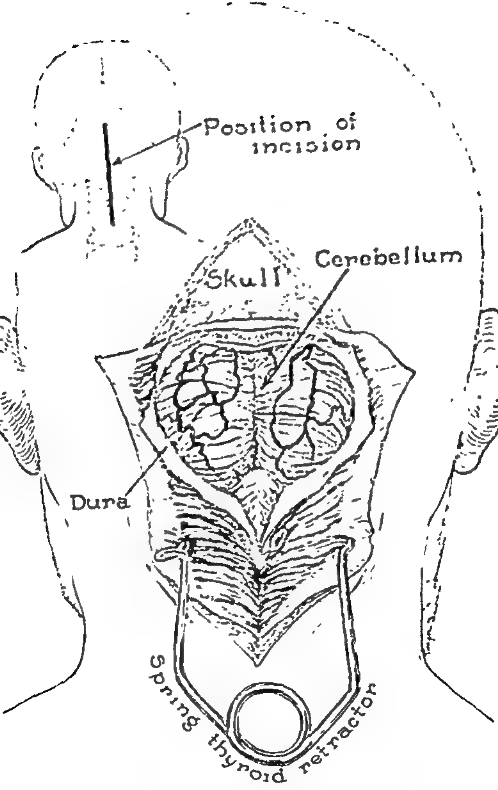


Fig 17-29 Bilateral exposure through midline incision.

For suspicted midline tumors or cerebellar growths, bilateral exposure is required (Fig. 17-29) and is accompanied by removal of the arch of the atlas to free the herniation of the cerebellar tonsils. Sufficiently wide exposure, particularly in children or in adults with long necks, may be obtained

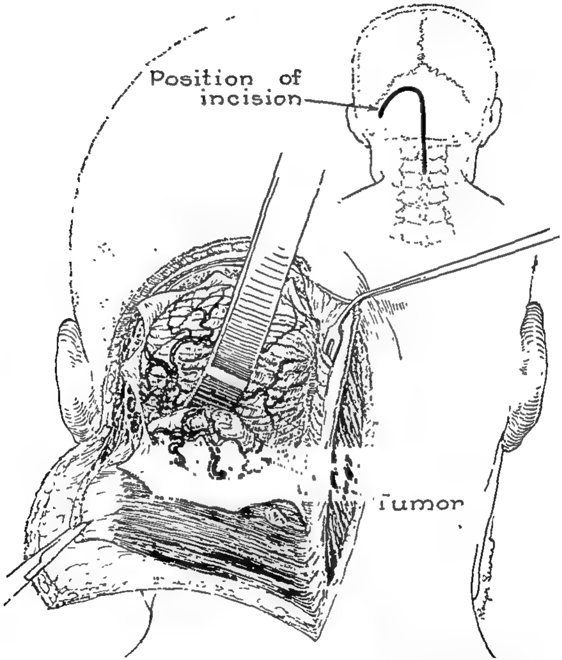
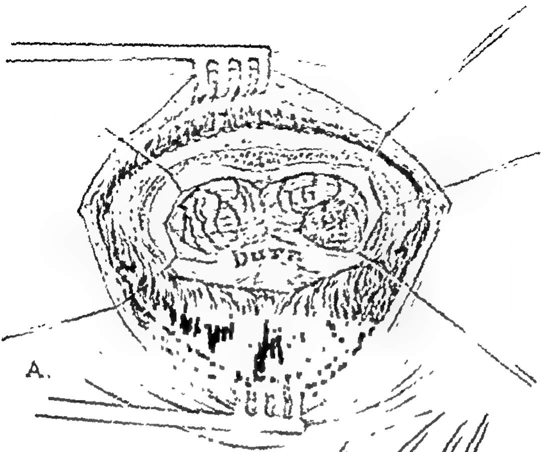


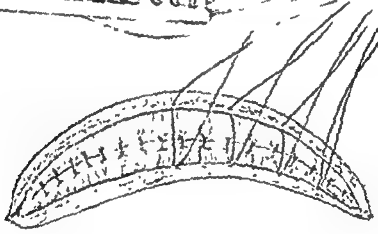
Fig. 17-30. Unilateral exposure for brain tumors through a suboccipital craniectomy

by a long midline incision, dissection of the scalp well back from the deep fascia, a cross incision of the muscles for 3 or 4 cm. close to their superior attachment, and subperiosteal separation of them from the occipital bone.

In unilateral exposure (Fig 17-30) the dura may or may not be opened in a flap-like manner and later closed, while a stellate opening is employed in bilateral exposure and the dura is left open. The occipital sinus lies in the midline of the dura and must be clipped, sutured, or coagulated (Fig. 17-31).



A.



B.

Fig 17-31 A, dura opened in stellate manner showing tumor in right cerebellar hemisphere B, closure of fascia and muscle, galea, and scalp in layers with interrupted sutures.

Tumors in this region must be dealt with depending upon their nature and location. Some may be completely removed, while others do not lend themselves to more than partial removal The brain stem tolerates very little manipulation and extreme care in working about it is necessary to avoid serious postoperative complications.

Meticulous care in closure of muscles, fascia, galea, and scalp will prevent formation of false meningoceles or spinal fluid leaks.

Convulsive states resulting from cortical scars may be attacked surgically, and with considerable success in some cases. The reader is referred to the work of Penfield and Erickson(2) for a more detailed account of this work.

The surgical treatment of internal hydrocephalus has been described by Dandy and Lewis(3) with further discussion by Putnam(4).

Surgery of the Orbit. Operative treatment of lesions of the lids, the globe, and extrinsic muscles of the eye and of tumors on the anterior portion of the orbit lie within the province of the ophthalmologist. Neoplasms of the retrobulbar spaces, extensions from anteriorly placed tumors, intracranial tumors with orbital involvement, and decompression of the orbital contents in dangerously progressive exophthalmos have fallen into the field of the neurologic surgeon.

Unilateral lesions are approached through a low frontal osteoplastic flap and elevation of the dura from the orbital plate which is then removed. The bone removal required depends upon the extent of the lesion and the need for decompression of the contents. The operation is entirely extradural. Opening of the frontal or ethmoid sinuses must be avoided.

For severe progressive exophthalmos bilateral operations are usually required. A Souttar scalp incision (Fig. 17-32) is employed with decompres-

Fig 17-32 Area of bone removal for orbital exposure or decompression

sion of one orbit or both at the same sitting. If exophthalmos is sufficiently severe to demand decompression, the widest bone removal is required. Operations of less extent have been performed for cosmetic reasons but are inadequate for severe conditions Prior to major operations upon the orbit the lids are lightly sutured together and light compression dressings are used for approximately a week after operation to lessen postoperative edema.

The surgical approach to malignant exophthalmos has been detailed by Dr. H. C. Naffziger(5, 6).

Lobotomy, or frontal lobectomy, has been employed in an attempt to overcome certain types of mental derangements. A monograph by

Walter Freeman and James Watts(7) describes the clinical problems and their surgical treatment.

Intracranial aneurysms and their surgical treatment are well described in a monograph by Dr. W. E. Dandy(8).

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18

THE SPINAL CORD

Cobb Pilcher and William F. Meacham

Surgery of the spinal cord requires the mastery of two diametrically opposed types of technic. The cord, like the brain, is protected by a heavy armor of bone and its surgical exposure is a strenuous and muscular task which involves the forcible retraction of the heavy muscles and the deliberate removal and sacrifice of part of the bony covering with heavy and, in a sense, crude instruments and methods.

On the other hand, the spinal cord, itself and its attached nerves and immediate coverings are structures of greatest delicacy which must be handled, if at all, with the most meticulous gentleness and specialized fine instruments.

Knowledge of and experience in these technics are essential for successful surgery of the spinal cord and this exacting form of surgery should never be attempted by the unassisted novice. However, such a warning and such a restriction need not contraindicate the setting forth in this volume of the principles of spinal cord surgery, since both the beginner and the physician or surgeon in other fields may well profit by familiarity with them.

SURGICAL ANATOMY AND SURGICAL PHYSIOLOGY

The Spinal Column. From the viewpoint of surgical approach to the spinal cord, the operator must be particularly familiar with two anatomic features: the normal curvatures of the spine and the variations in structure of the spinous processes and posterior arches (laminae) at different levels of the spinal column (Fig. 18-1).

In the cervical region, the spine has a marked anterior (lordotic) curvature and the heavy posterior cervical muscles must be carefully separated in the midline and retracted before the spine is reached. The cervical vertebrae are small and their laminae close together. The first (atlas) has no spinous process, but only the narrow arches which meet with a small bony prominence in the midline. The second (axis) has a short heavy bifid spine and the third, fourth, fifth, and sixth vertebrae have longer, thinner spinous processes which are bifid at their posterior extremities. They protrude directly backward from the centers of their respective arches. The seventh cervical spine is much longer, slants a little caudally, and is not usually bifid.

In the thoracic region, the curve is reversed and is convex posteriorly (kyphotic). The vertebral bodies and arches are heavier and the long, narrow spinous processes are directed caudally so that their tips lie over the next lower vertebral arches.

The lumbar spine again assumes an anterior curvature ending in the backward-flaring broad sacrum which is, of course, attached to the pelvic girdle. The lumbar vertebral bodies are the largest in the spine and their arches are also heavy. Their spinous processes are broad, flat and have long posterior surfaces in the longitudinal direction.

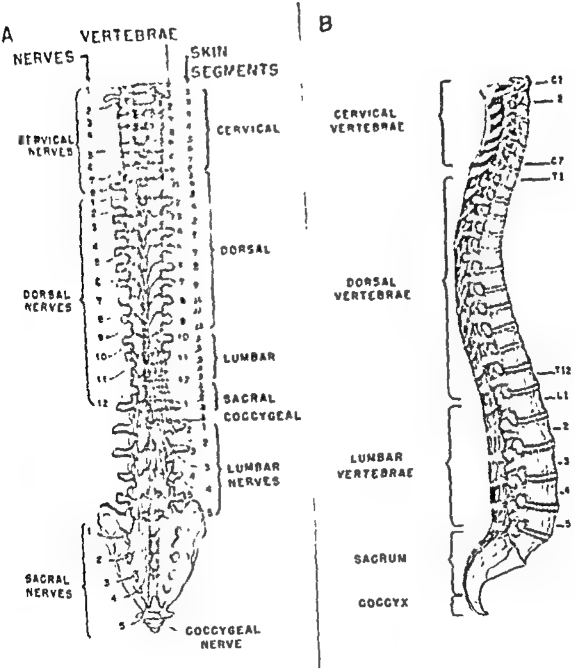

Fig. 18-1. Surgical anatomy of the spinal column. A, relation of the vertebrae to the respective cord segments and spinal nerves. (After Elsberg[6].) B, the normal curvatures of the spine and the shape of the spinous processes (shown in black, beneath the veil of the interspinous ligaments).

Occasionally, the twelfth dorsal vertebra has only rudimentary ribs or the first sacral vertebra is not completely fused with the remainder of the sacrum. Either of these anomalies can give rise to the erroneous roentgenographic impression that the patient has six lumbar vertebrae. From the standpoint of neurologic localization in such cases, it is important

to determine the precise nature of the anomaly and it may be necessary to make roentgenograms of the entire dorsal spine in order to count the vertebrae. A similar anomaly which is not uncommon is the presence of cervical ribs arising from the seventh cervical vertebra. Throughout the spinal column, the spinous processes are united by interspinous ligaments and the posterior arches by the ligamenta flava. These structures as well as the general configuration of the spinal column are shown in Figure 18-1. The articulations should be studied in greater detail in a textbook of anatomy.

The Spinal Canal and Meninges. Inside the spinal canal is a variable amount of loose epidural fat. Anterolaterally is a continuous plexus of veins which are thin-walled, collapsible and very friable.

The dura mater is a tough membrane which is not very vascular. It sends a dural sheath out along the emerging pairs of nerve roots into the intervertebral foramina for a short distance. Closely subjacent to the dura is the thin spidery arachnoid within which cerebrospinal fluid circulates freely. The pia mater is a thin but rather tough covering of the spinal cord itself. A thin, tough membrane, the dentate ligament, runs longitudinally along the midlateral region of each side of the spinal cord and is attached to the dura by roughly segmental pairs of denticulations which suspend the cord in its bath of cerebrospinal fluid wthin the dural canal.

The Spinal Cord and Spinal Nerves. The spinal cord which is, of course, a continuation of the medulla oblongata extends from the foramen magnum down to approximately the upper border of the second lumbar vertebra. Its lowermost portion, the conus medullaris, tapers to a conical point and terminates in the filum terminale. In the cervical and lumbar regions are the well known enlargements of the cord corresponding to the increased nerve supply required by the upper and lower extremities respectively.

The pairs of posterior roots arise from the cord dorsolaterally and the anterior roots ventrolaterally, and emerge through the intervertebral foramina.

Due to the embryologic cephalic displacement of the cord, with its ultimate termination at the level of the second lumbar vertebra, the spinal nerve roots assume a progressively more and more downward direction in the spinal canal from above downward. Thus the cervical nerve roots run almost directly laterally into the intervertebral foramina whereas the lower dorsal roots have a downward course and emerge from two to three vertebral levels below their point of origin in the spinal cord. The lumbar and sacral roots, of course, extend directly downward from the lower end of the cord, forming the cauda equina and emerging far below their points of origin in the cord. This difference of direction of spinal nerve roots and the corresponding different levels of spinal segments with reference to their respective vertebrae is of great importance in localizing diagnosis and surgical approach. The various relationships are shown in Figure 18-1A.

The intricacies of the microscopic anatomy and physiology of the spinal cord are at first glance so complex in function and minute in structure as to frighten the most determined surgeon. Fortunately, however, the very complexity of the spinal cord is due so much to duplication of function and bilaterality of representation that the localizing physiology

from a purely surgical point of view is actually relatively simple (Fig 18-2).

The most important single localizing diagnostic phenomenon associated with surgical disorders of the spinal cord is the existence of loss or impairment of function on one or both sides *below a given level*. In the understanding of lesions which are incomplete, whether they be spontaneous or surgically produced knowledge of the pathways of three par-

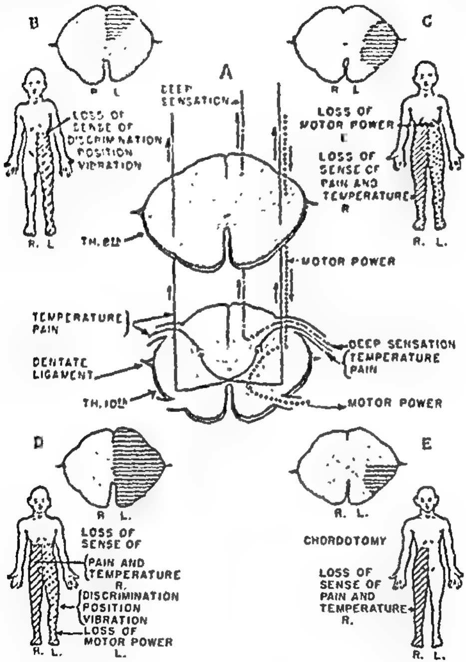

Fig 18-2 Surgical localization in the spinal cord. A, the pathways of the three major functions B, C, D, and E, syndromes produced by unilateral lesions

ticular functions is essential. These are. 1, posterior column function consisting essentially of muscle and joint sense and vibratory sense; 2, pain and temperature sensations which are transmitted in the anterolateral spinothalamic tracts; 3, voluntary motor power most of which is carried in the more dorsal portion of the lateral column (Fig. 18-2A). The essential points are that the deep sensation of each posterior column has its origin on the

same side of the body, pain and temperature sensation in each spinothalamic tract arises in the opposite side of the body and the motor power of each pyramidal tract will be distributed to the muscles of the homolateral side. The clinical pictures which may be produced by injury, disease or surgical section of a portion of the spinal cord at a given level are shown in Figure 18-2B, C, D, and E.

It is worthy of mention that the pathways of tactile sensation are poorly understood Some fibers run in the posterior columns, some in the ventral spinothalamic tract. Some are uncrossed and some filter across the midline over a considerable length of the spinal cord. For this reason, loss or impairment of tactile sensation is not a reliable localizing diagnostic phenomenon.

LAMINECTOMY

Preoperative Preparation. Preparation for laminectomy should be much the same as that employed for any major operative procedure. If the operation is not urgent, care should be taken to eliminate all possible infections, particularly those due to the frequently encountered bed sores and urinary infection (see postoperative care below). The bowel should be thoroughly cleansed the preceding evening. A barbiturate should insure a night of rest and relaxation. Morphine and atrophine should be given 30 minutes before induction of ether anesthesia if the latter is to be used. The skin should be carefully shaved immediately before operation.

The Technic of *Laminectomy.* Proper equipment is an essential in spinal cord surgery. A strong suction machine, an adequate electrosurgical unit, and appropriate bone instruments are no less essential than are the fine bayonet forceps, the tiny blunt dissecting instruments and the fine French-eye needles to be employed after the dura is opened. An operating table which can be broken in order to flex the spine at the operative site is helpful and a cerebellar headrest is essential for cervical and high dorsal laminectomies

In most instances, the anesthetic of choice is intratracheal ether. By this method, the anesthesia and relaxation are smooth and an easy method for administering artificial respiration is provided if it should be necessary (it is particularly important in cervical laminectomies). Local procaine anesthesia may be used quite satisfactorily for laminectomy and is frequently preferable for the operation of chordotomy (see below). It must be remembered, however, that traction on posterior spinal roots is extremely painful and these cannot be satisfactorily anesthetized by local methods. Intravenous sodium pentothal anesthesia is preferred by some surgeons and should be accompanied by the administration of oxygen.

The steps of the operative procedure are shown in Figure 18-3. The skin is prepared by the surgeon's preferred method The incision is in the midline and should extend almost the width of one vertebra above and below the proposed length of bone removal.

For cervical laminectomy, the incision has to reach well up on the scalp and usually down to the level of the first or second dorsal spine. Here, it is most important to keep the incision exactly in the midline between the longitudinal muscles in order to minimize hemorrhage from

these muscles. This will be facilitated by keeping retractors on each side with exactly the same amount of traction on each.

In the thoracic and lumbar regions, the spinous processes are encountered directly beneath the deep subcutaneous fascia without separation of muscles.

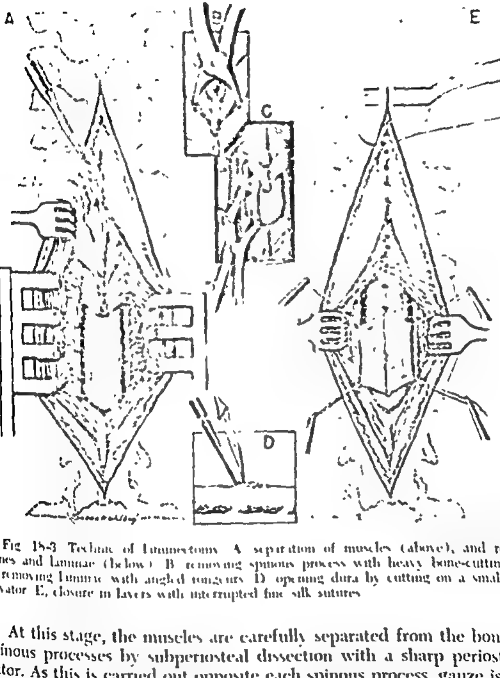

Fig. 18-3. Technic of laminectomy. A, separation of muscles (above), and removal of spines and laminae (below). B, removing spinous process with heavy bone-cutting forceps. C, removing laminae with angled rongeurs. D, opening dura by cutting on a small, grooved elevator. E, closure in layers with interrupted fine silk sutures.

At this stage, the muscles are carefully separated from the bone of the spinous processes by subperiosteal dissection with a sharp periosteal elevator. As this is carried out opposite each spinous process, gauze is packed into the opening to control hemorrhage until the muscles can be retracted (Fig. 18-3A).

The tough fascia on each side which is continuous with the interspinous ligaments is divided between vertebrae and with the periosteal elevator, the muscles are stripped from the underlying laminae and are retracted with self-retaining laminectomy retractors (Fig. 18-3A).

The spinous processes are then cut away with an angled bone forceps (Fig. 18-3B), bleeding from their stumps being controlled with bone wax, if necessary.

In the same manner, the posterior arches are removed with angled rongeurs, disclosing the underlying dura (Fig. 18-3C). The bone of the laminae should be bitten away laterally almost to the articular processes but not into the facet joints.

At this stage, troublesome bleeding from the very thin-walled anterolateral epidural veins is almost always encountered. This is best controlled by the application of gelatin sponge or fibrin foam soaked in thrombin. These absorbable materials are applied in small thin pledgets, temporarily covered with moist cotton strips and sucked almost dry. The cotton may be removed after a few seconds and the procedure continued.

After the bone is removed, no gauze should be employed in the operation The muscles are covered with broad strips of moist cotton and thin strips or pledgets of the same material are subsequently used as sponges. Great care must always be taken not to traumatize the cord. It is never rubbed, even with cotton. Suction on the cotton pledgets keeps the field clean when blood or cerebrospinal fluid obscures the exposure

The dura should be opened first at the upper margin of the exposed area, particularly if obstruction of the canal has been demonstrated to be present. If the opening is above the obstruction, a free flow of cerebrospinal fluid will take place. If such a flow does not occur, the surgeon must carefully reconsider his localization and perhaps insert a very small soft rubber catheter upward through the small opening in the dura to make certain that his exposure is not too low.

The dura is opened first by elevating it with a tiny, sharp hook and nicking it with a pointed knife. It is not essential as sometimes claimed to avoid opening the arachnoid at this point. As soon as a small nick is made, a grooved, angled elevator is inserted through it and the remainder of the dural opening carried out in the midline by cutting on this elevator with a pointed knife, thus protecting the underlying cord (Fig. 18-3D).

The dural edges are held apart by retention sutures and the subsequent intradural procedure varies with the type of lesion to be dealt with (see below). Regardless of the nature of the lesions to be dealt with, certain principles in intradural spinal surgery are paramount. Cotton pledgets and suction should be used for cleansing the field. Clamps and coagulation should not be used close to the core or spinal roots. Fortunately, extensive intradural bleeding is rarely encountered and most vessels can be controlled easily by very gentle pressure of a fragment of moist cotton. Points which continue to bleed can eventually be handled by the application of gelatin sponge or fibrin foam soaked in thrombin, or by the application of a very small muscle stamp. Narrow aluminum brain retractors may sometimes be used upon the cord but only with the greatest gentleness.

After the intradural portion of the operative procedure has been completed and hemostasis secured, the dura should be closed tightly in the great majority of cases. This is done with closely placed fine interrupted silk sutures, carried on tiny French-eye needles.

The remainder of the closure is carried out in multiple layers with the same material. Formerly, heavy wire sutures were used to approximate the muscles in order to fill the dead space caused by the removal of bone. This is unnecessary, however, and several layers of silk sutures are prefer-

able. The essential layer is that of the heavy, deep fascia to which are attached some portions of the interspinous ligaments. Sutures of this layer should be very closely placed, tightly tied, and subsequent palpation should reveal no defect in the suture line. The subcutaneous tissues and skin are similarly approximated with interrupted silk (Fig. 18-31E).

Unilateral laminectomy is of value in suitable cases, particularly those in which an extradural procedure is to be carried out as in removal of a protruded intervertebral disc or, as preferred by some neurosurgeons, when a unilateral chordotomy is to be performed.

In this procedure, the muscles are dissected away on only one side, spinous processes are not removed. The laminectomy is begun by removal of the ligamentum flavum between two of the laminae and subsequent removal of bone for as great an extent as desired with rongeurs. The exposure so secured is quite limited and the procedure should be restricted to those operations which can be carried out through a very small opening.

Postoperative Care. Extensive and prolonged operative procedures within the spinal canal frequently result in a state of primary shock, probably resulting from intense bombardment of vasomotor centers by innumerable nerve impulses. In addition, loss of blood may sometimes be extensive. In the presence of a persistent low blood pressure, the surgeon should not hesitate to resort to blood transfusion at an early time.

Following cervical laminectomy, severe hyperthermia is a common complication. This is a neurogenic phenomenon due to trauma to the cervical cord and must be combated by physical means. Frequent sponging of the skin with alcohol, the play of an electric fan over moist skin, administration of salicylates and in severe cases the use of ice water enemas are methods of value.

Food may be taken as desired and fluids should be forced, particularly if bladder paralysis is present.

There is no contraindication to the use of morphine or other narcotics in the first few postoperative days to combat pain.

For the first few days, the patient should not be allowed to lie perfectly flat on his back, but no cast or other form of immobilization is necessary after laminectomy.

In no type of surgical case is nursing care more important than in postoperative spinal cord cases. The two great essentials are the care of the skin and the care of the bladder.

In the presence of paralysis and anesthesia, there is also impairment or loss of reflex control of circulation to the skin with resultant inadequacy of cutaneous oxygenation and nutrition. Since anesthesia prevents the patient from knowing when the skin is irritated, extensive damage may occur without his complaining. In addition, these patients are likely to have suffered loss of weight, particularly of subcutaneous fat, with resultant increase in the prominence and proximity to the surface of bone protuberances such as sacrum, femoral trochanters, lateral surfaces of knees and ankles, and the heels. Relatively enormous pressure sores can occur in a surprisingly short space of time.

The best treatment of the skin is of course preventive. The patient's position should be changed every hour or at most every two hours. Gentle

massage of the skin over bony prominences improves the circulation. It is absolutely essential that the bed be kept dry. Gauze and cotton "doughnuts" under bony protrusions are helpful and rubber rings protect the sacrum. Pneumatic mattresses are very valuable. Special beds have been devised for mechanical changes in patients' positions but are not essential.

Once a break in the continuity of skin occurs, it must be regarded as a major surgical wound and every precaution taken to avoid infection. Frequent, careful dressings with aseptic methods, cleansing of ulcerated areas, débridement of sloughing tissue and the application of a bland ointment such as zinc oxide to the surrounding skin are useful measures. Sterile dressings should be applied at all times and the use of adhesive tape reduced to a minimum to avoid further skin irritation.

The care of the paralyzed bladder is to some extent a controversial subject. In the final analysis, the method of treatment must be chosen on the merits of the individual case with consideration of the probable duration of the paralysis, the economic and intellectual status of the patient and the judgment and experience of the individual surgeon.

In all cases who have retention or incontinence of urine immediately after operation, the tidal drainage method introduced by Munro is preferable. This is an automatic device for irrigating, stretching and emptying the bladder periodically. A suitable type of tidal drainage apparatus is shown in Figure 18-4. It has the advantages of preventing both distention and contracture of the bladder and holding urinary infection to an irreducible minimum. The simple indwelling catheter should never be employed without tidal drainage for more than two or three days at most. Similarly, repeated catheterization carries a great risk of infection. Manual expression of a greatly distended bladder is a dangerous procedure and should be employed, if at all, only with great caution and under unusual circumstances.

In patients whose urinary retention is expected to be very prolonged or permanent, as in the case of many spinal cord injuries, the bladder may be treated in one of two ways:

The first is the prolonged employment of tidal drainage with removal of the catheter after a period of several weeks for longer and longer periods, thus giving the patient the opportunity of developing an "automatic" bladder. This is the development of a reflex mechanism which causes the bladder to discharge its contents automatically when it reaches a certain degree of distention or when some stimulus such as pinching the thigh or lower abdomen produces a reflex contraction of the bladder musculature. Many patients develop this to a very efficient degree and can establish surprisingly regular bladder habits. Unfortunately, all patients cannot develop automatic bladders and prolonged efforts to produce this mechanism may result in chronic distention of the bladder with the inevitable danger of retrograde infection and renal damage. The development of automatic function of the bladder may be enhanced by section of anterior roots including the sacral roots in instances where severe spasm exists. In other cases simple section of the sacral nerves in the sacral foramina may be helpful.

The second method of treatment is the employment of suprapubic

cystostomy. This method if carried out high in the lower midline preserves a fair bladder volume, provides a ready method of irrigating the bladder and probably carries less danger of infection and renal injury than any other method. The suprapubic tube may be clamped off for long periods and drained at will. It can be removed, cleansed and replaced without difficulty and its employment requires little patience, intelligence or expense on the part of the patient.

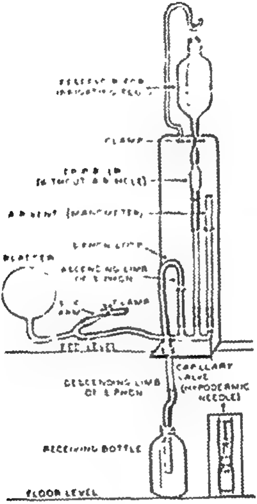

Fig. 15-1 Diagram of tidal drainage apparatus.

In cases of permanent urinary incontinence, which fortunately are rare, the employment of drainage bags worn under the clothing in the males and perineal pads in the female are necessary and are troublesome. In very severe cases, ureterorectal anastomosis may be necessary.

Physiotherapy is frequently a useful adjunct in rehabilitation of patients with spinal cord disorders. Hydrotherapy, massage, passive exercises, and possibly electrotherapy are helpful in combating spasticity, improving circulation, and muscle reeducation.

CONGENITAL MALFORMATIONS

Spina Bifida with Meningocele. Spina bifida is the defect produced by failure of fusion (or indeed sometimes failure of formation) of the posterior arches of one or more vertebrae. It is most common in the lumbar

region and may occur to a mild degree as spina bifida occulta without neurologic complications or significant clinical effects.

When it is marked, however, there may occur in the prenatal period a gradual protrusion of the dura through the opening with formation of a large sac. This pushes the skin ahead of it and frequently results in great

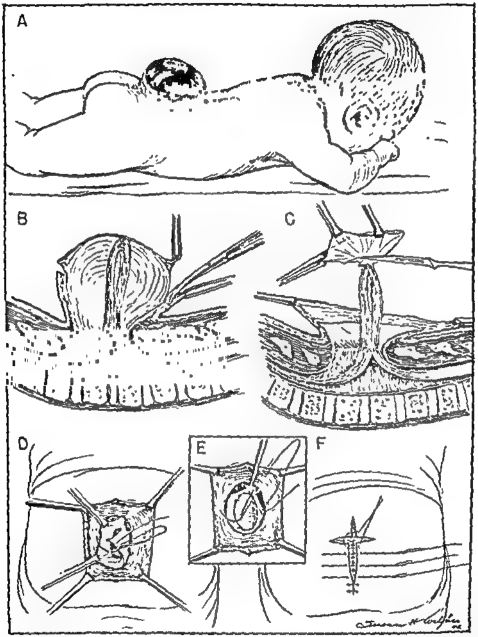

Fig. 18-5 Removal of lumbar meningocele. A, the sac is thin and shiny and partly ulcerated. B, viable skin is dissected off of the dura. C, the integrity of the cauda equina is carefully preserved. *D*, the dura is imbricated. E, flaps of lumbar fascia form a makeshift spinal canal. F, subcutaneous tissues and skin are sutured. Excision of redundant skin produces transverse incisions. (After Naffziger and Boldrey (16).)

thinning and ulceration of the skin (Fig. 18-5A). When it occurs in the lumbar region, the nerves of the cauda equina are usually adherent to the apex of the sac and are pulled outward with its growth, forming a loop (Fig. 18-5B) and incidentally pulling the cord downward in the spinal canal. In the dorsal region, the sac usually contains only cerebrospinal fluid but occasionally a distorted cord is enclosed within it.

Paralysis and anesthesia of the lower extremities may be present at birth as may also ulceration and leakage of cerebrospinal fluid from the sac. Due to traction upon the spinal cord, the lower brain stem and the tonsils of the cerebellum may be pulled downward into the spinal canal resulting in blockage of the outflow from the fourth ventricle and the production of obstructive hydrocephalus (Arnold-Chiari malformation).

Occasionally, the arches of all or a great part of the lumbodorsal spine are missing and the spinal cord is found covered with only a thin, translucent membrane which is often ulcerated and leaking. This condition is called rachischisis and can only rarely be improved by operation.

Some small flat meningoceles retain a heavy covering of skin and produce no neurologic symptoms. These should not be operated upon unless evidence of growth can be demonstrated.

Decision to adopt surgical treatment of the large meningoceles which are ulcerated, which may or may not have resulted in paralysis and which may or may not be accompanied by hydrocephalus, is difficult. The parents should be told plainly that the results may be bad but it is probably wise to make the attempt in nearly all cases. If the sac is leaking or about to leak, and if hydrocephalus is developing, the operation should be done within a few days of birth. If no leakage is present and growth of the sac is not rapid, it is preferable to wait for four to eight weeks.

The child should be fed to within two hours of operation. The anesthetic should be very light ether, begun after the patient is draped. Great care should be taken to avoid loss of blood since loss of even a very small amount may be serious in small infants.

Elliptical incisions should be made in such a manner as to preserve a maximum of useful skin for closure. Skin should be dissected away from the dural sac, down to the neck of the latter if possible (Fig. 18-5B), but frequently the sac will be too thin and friable and will be torn. After the skin flaps have been laid back, the sac should be opened (or the opening in it enlarged) well to one side of the midline. Inspection of its interior will then nearly always show the bundle of nerve filaments of the cauda equina emerging from the spinal canal above the neck of the sac and extending up to the apex of the dural envelope (which is still, of course, covered by the thin skin or ulcerated area left in place by the original incisions).

The opening in the dural sac should next be carried all the way around well above its neck in order to preserve a dural layer for closure. The apex of the loops of nerves of the cauda equina should then be dissected from the sac with the greatest possible care. This is best done with a very sharp knife and should be so planned as to leave an extremely thin layer of the dural membrane attached to the nerves rather than to risk cutting through any of them (Fig 18-5C) At times, it becomes necessary actually to leave a bit of the macerated and ulcerated epithelium and this is preferable to damaging the nerves When this dissection is completed, the main portion of the sac is discarded and the cauda equina dropped back into the rudimentary spinal canal The latter may consist simply of an open trough or even a flat surface

Repair must be done with great care. If enough dura is available, it

should be imbricated in a double layer over the cauda equina, even when the latter tends to bulge out of the incomplete canal (Fig. 18-5D). Often a single suture line is all that can be utilized.

Incisions are then made in the rather strong lumbar fascia well above the vertebral ridges on each side and the deeper portions of this fascia dissected free and used as flaps to turn over the dural suture line (Fig. 18-5E). These flaps of fascia are closed with fine stitches of interrupted silk as in the case of the dura. In some instances, it is then possible to use the peripheral edges of the incised fascia as a third layer in the closure but this may not always be feasible. It should be employed, if possible, and subsequently the subcutaneous tissue and skin should be closed with interrupted silk. It is necessary frequently to cut away redundant skin and sometimes to make transverse incisions in order to avoid an ugly protrusion of folds of skin (Fig. 18-5F).

In the dorsal region, it is usually possible to follow the same procedure but simply to cut off the dural sac if it contains only cerebrospinal fluid and to close its neck, with subsequent repair as circumstances permit.

The Arnold-Chiari Malformation. If obstructive hydrocephalus is developing in the presence of a lumbar meningocele, it is due to the traction deformity of the brain stem and cerebellum already mentioned. Operative treatment of this should precede removal of the meningocele only when hydrocephalus is developing rapidly and imminent leakage from the meningocele is not feared.

The operation consists of cervical laminectomy with additional removal of a semicircular area of bone from the occiput above the foramen magnum. It is usually necessary to remove the laminae of at least the upper three cervical vertebrae. It is essential to get below the lowermost extension of the thin and fibrosed tonsils of the cerebellum.

When the dura is opened, it will be found that there are dense adhesions binding the fibrous tonsils to the underlying brain stem and cord (Fig. 18-6B). These adhesions must be dissected free with the greatest possible care and the tonsils removed upward to a point where there is free flow of cerebrospinal fluid from the obstructed fourth ventricle (Fig. 18-6A). Sometimes it is necessary to leave a thin rim of cerebellar tissue adherent to the medulla laterally rather than risk injury of this structure in the dissection.

It is equally essential that adequate decompression be obtained in the occipital region to permit the upward flow of cerebrospinal fluid over the structures of the posterior fossa and through the incisura. However, even with the most extensive procedure and careful dissection adhesions may reform and the hydrocephalus may continue to grow worse

The dura should usually be closed but the authors have occasionally thought it wise to leave the dura open.

Basilar Impression (Platybasia). This congenital deformity consists of an upward displacement of the upper cervical spine producing a caving in of the floor of the skull in an upward direction and in a sense forcing the anterior wall of the foramen magnum upward about the brain stem. This may produce constriction of the brain stem and traction upon its emerging nerves, sometimes with neurologic symptoms of great severity.

Diagnosis is made by roentgenography, particularly the lateral projection of the skull in which it is seen that the odontoid process and anterior portion of the atlas lie above rather than below a line drawn from the dorsal lip of the foramen magnum to the hard palate (Chamberlain).

The operative treatment consists in wide decompression by laminectomy of the upper cervical vertebrae and removal of the inferior portion of the occipital bone from the foramen magnum upward. Except that it is usually carried out in adults, it is almost an identical procedure with that just described for the Arnold-Chiari malformation in infants (in so far as the decompressive exposure is concerned).

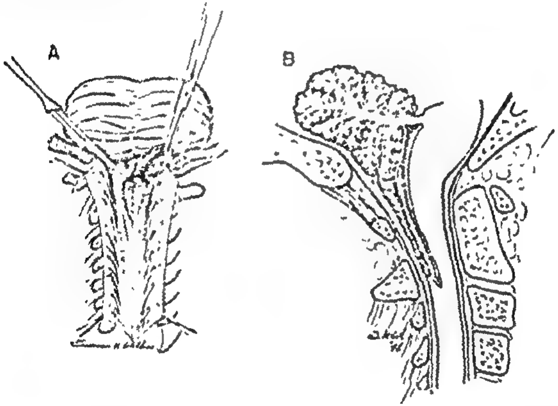

Fig 15-6 The Arnold-Chiari traction deformity A, dissection of the herniated, adherent and fibrosed cerebellar tonsils thus opening the fourth ventricle Note cervical nerves coursing upward due to downward displacement of cord B, lateral diagram of the deformity

Angiomatous Malformations. Congenital venous angiomas and rarely arteriovenous malformations occur in the spinal cord. They may be fairly well localized or extremely extensive, sometimes involving the entire length of the spinal cord.

They evidently have a tendency to enlarge either through dilatation of individual vessels or possibly through proliferation of vascular channels since symptoms arise from them usually in early adult life rather than in early childhood.

The symptoms usually result from cord compression and tend to be localized even though the lesion may be very extensive. This may lead to the mistaken diagnosis of an isolated cord tumor and hence to operative exploration.

At operation, when the dura is opened, there is encountered a tangled mass of distended vessels, usually venous They are worm-like and tortu-

ous and any attempt at operative removal is foolhardy. The wound should be closed promptly and radiation therapy should be given later. This treatment has surprisingly beneficial results in a number of cases although the mechanism of its action is unknown.

INJURIES

We are concerned in this chapter only with those injuries of the spine in which the spinal cord or its emerging nerves are damaged, and not with the uncomplicated fractures or dislocations which fall in the realm of orthopedic surgery. Acute injuries of the spinal cord are among the most discouraging lesions in surgery since function lost as the result of violent trauma to the spinal cord is rarely recovered.

Fractures and fracture dislocations which result in injury of the cord or cauda equina are most common in the cervical and lumbar regions where mobility is greater and the protecting cage of the ribs is not present. Of all vertebrae, the fifth and sixth cervical and the first and fifth lumbar are the most frequently involved.

Cervical cord injuries result usually from falls on the head and may accompany severe brain injuries. They should always be sought for in cases of traumatic unconsciousness. The clinical picture of the midcervical cord injury is classic. The arms are flexed at the elbows, the biceps reflex is present, the triceps reflex is absent and the sensory level corresponds to the fifth cervical segment. Respiration is entirely phrenic. Hyperthermia is not uncommon and a bilateral Horner's syndrome is present.

In the dorsal region, the clinical picture corresponds to the *vertebral* level (compare Fig. 18-2A). The upper lumbar picture is one of paralysis of both lower extremities with corresponding loss of sensation. Sometimes a little sensation will remain in the first lumbar distribution.

When damage to the cauda equina results from injury of the lower lumbar spine, the sensory and motor loss may be patchy. Incontinence of urine may be present and spasticity with overactive reflexes and pathologic toe signs do not develop.

The Transportation of Cord Injuries. Moving patients with injuries of the spine in whom spinal cord injury is present or is imminent is a dangerous procedure. Great care should be taken never to twist the back. The patient should always be turned "in one piece" and should be lifted without movement of the spine if possible.

Some authorities advise transportation of such patients on the abdomen in order to enhance extension of the spine but this is unnecessary if a folded sheet, pillow or other elevation is placed under the approximate site of the injury. In cervical injuries, sandbags or other splinting objects should be placed beneath the neck and beside the head.

In the handling of such patients in the hospital, particularly in the roentgenographic room, every precaution should be taken against excessive movements of the affected portion of the spine.

Skeletal Traction. In cases of dislocation of the cervical spine, the application of skeletal traction is often an exceedingly valuable procedure

whether or not laminectomy is undertaken (and whether or not a cord injury is present). Severe dislocations can be reduced with safety and maintained in a state of reduction by this method.

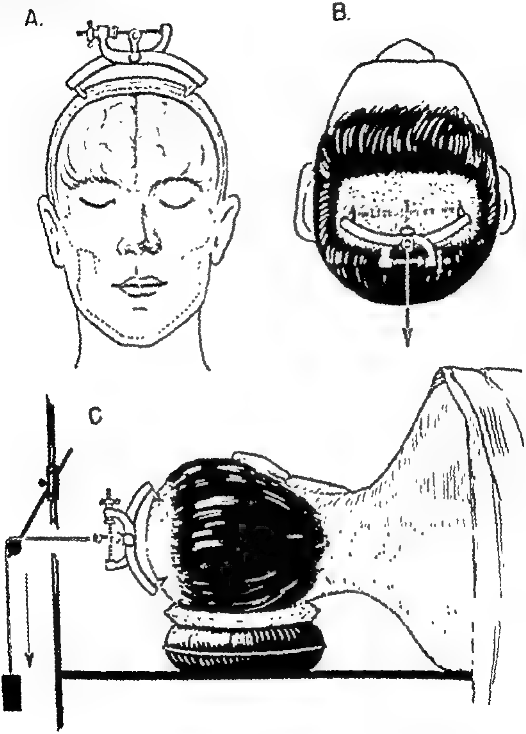

Fig. 18-7 Application of Crutchfield tongs for skeletal traction in cervical injuries. (After Naffziger and Boldrey(16).)

The preferable method of applying skeletal traction is by use of Crutchfield tongs. After shaving and preparation of the scalp, two tiny nicks are made in the parietal region under local anesthesia. Small drills with special guards to prevent penetration of the inner table are used to drill holes which should point diagonally inward in the direction of the prongs of the tongs (Fig. 18-7).

The tongs are then inserted and tightened firmly in this position. A small cotton-collodion dressing is all that is required.

Traction should be begun with 5 to 10 pounds and may be increased within 24 hours to 15 or 20 pounds. With the tongs in position and traction being made, the patient may turn from side to side without difficulty and the skeletal traction does not interfer in any way with use of his jaws as in the case of halter traction. Such traction may be maintained for three to six weeks if necessary.

Operative Treatment. Decision regarding the wisdom of operation in acute cord injuries is an exceedingly difficult one. If paralysis and loss of sensation are instantaneous and complete at the time of injury, no hope whatever of return of function exists, and operative treatment is useless. It must be remembered, furthermore, that the only thing to be accomplished by operation is decompression. Thus, operation cannot be expected to be of benefit unless evidence of continuing cord compression is present. In the authors' opinion, operative decompression should be undertaken only if one or more of the following conditions exists:

1. Incomplete or delayed paralysis and anesthesia.
2. A positive Queckenstedt test indicating blockage of cerebrospinal fluid.
3. Roentgenographic evidence of bone fragments protruding into the spinal canal.
4. The existence of fractures of the posterior arches or dislocations of the posterior articulations in cases in which traction manipulation methods are planned for reduction. In such cases, with or without the circumstances listed above, operative decompression may be indicated in order to avoid the risk of further damage to the cord resulting from manipulation

The time of operation is also exceedingly important. Greatest hope exists if it is carried out within 48 hours, but some surgeons feel that later operations are justifiable.

It is essential to remember that the criteria outlined above are not applicable to injuries of the cauda equina, in the roots of which regeneration is possible In the lower lumbar region, therefore, operative decompression is indicated in all cases and at all times in which continuing compression can be demonstrated either by lumbar puncture or roentgenographically

The *operative procedure* consists essentially of simple laminectomy. It must be remembered, however, that hemorrhage may obscure the anatomic picture and that fragments of bone may be free and protruding into the spinal canal. Great care should be taken to avoid creating further damage to the cord. The dura may be lacerated and the removal of bone should be carried out with even greater caution than usual.

In the majority of instances, the cord will be contused and swollen. It may be necessary to leave the dura open, although this should be avoided if possible. Severence of all or any portion of the cord is an irreparable injury and no attempt should be made to repair it. The denticulate ligaments should be severed on either side in order to prevent anchoring of the swollen, contused cord.

In rare instances, the lesion is hematomyelia or intramedullary hemorrhage. This will appear as a localized fusiform swelling of the cord, often with discoloration showing through the superficial layers of cord substance. In such instances, it is necessary to make a *midline* incision of the cord substance with a very sharp knife, avoiding surface vessels whenever possible. The clot within the cord may be evacuated by very careful suction and irrigation. The dura should not be closed until all bleeding, however slight, has completely ceased. Gelatin sponge or fibrin foam soaked in thrombin and applied in very tiny pledgets are invaluable for this purpose.

Penetrating Wounds. In penetrating wounds which involve the spinal canal and which are seen early, the factor of potential infection supersedes the questions of extent and time of appearance of cord symptoms. All such cases should be operated upon at the earliest feasible moment. Exploratory laminectomy should be carried out and should include thorough and careful removal of all foreign bodies, damaged tissues, bone fragments and blood clot. Thorough irrigation of the wound should be employed and small amounts of sulfanilamide dusted into the wound. Foreign bodies which have already traversed the spinal canal and are embedded in the bone or in organs elsewhere should be left alone or removed on the merits of the individual circumstances.

If the laminectomy and débridement are carried out within the first 12 hours, the wound should be closed without drainage. This may safely be done also in later cases if early chemotherapy has been instituted. If obvious infection is already present, drainage of the wound will be necessary but the drain should never be inserted inside the dura.

In very late cases, in which no infection has developed and in which there may be retained foreign bodies, decision regarding operation should depend upon a persistence of cord symptoms, evidence of continuing cord compression or the presence of foreign bodies or bone fragments within the spinal canal.

The Intervertebral Disc Syndrome. In recent years, it has been clearly demonstrated that the most common cause of sciatica is protrusion of a lumbar intervertebral disc with compression of an emerging nerve root. Similar disorders of the intervertebral disc with nerve root compression have been demonstrated with increasing frequency in the cervical region.

Lumbar Region. The great majority of disc protrusions occur at the fourth or fifth lumbar intervertebral spaces with compression of the fifth lumbar or first sacral nerves respectively in most instances. Conclusive clinical diagnosis can be made on the basis of one or more severe attacks of low-back pain with radiation down the posterior thigh, posterolateral leg, into the heel, the outer aspect of the foot or dorsum of the foot; paresthesia and diminished sensation in the area of the foot involved by pain; pain on straight leg raising exacerbated by flexion of the foot on the ankle (Lasegue's sign), increase of the pain on coughing or sneezing; diminished or absent ankle jerk, diminished mobility, particularly of anterior flexion in the lumbar spine due to pain and muscle spasm. A history of trauma may or may not be present but it is very likely that, even in those cases who have suffered no acute injury, chronic strain and trauma have

The tongs are then inserted and tightened firmly in this position. A small cotton-collodion dressing is all that is required.

Traction should be begun with 5 to 10 pounds and may be increased within 24 hours to 15 or 20 pounds. With the tongs in position and traction being made, the patient may turn from side to side without difficulty and the skeletal traction does not interfer in any way with use of his jaws as in the case of halter traction. Such traction may be maintained for three to six weeks if necessary.

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After the control of bleeding from the epidural veins, the retractor is withdrawn and the wound falls together nicely. It is closed in layers as already described with interrupted silk.

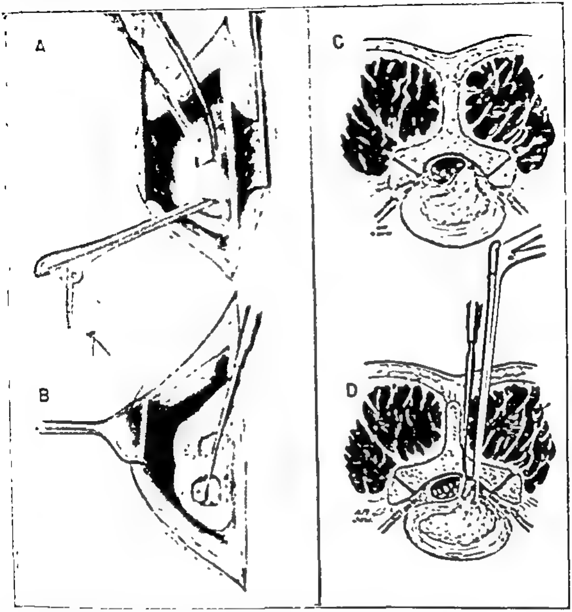

Fig. 16-8 Removal of protruded intervertebral disc A, excision of ligamentum flavum (above), and enlargement of interlaminal opening (below). B, retraction of dura and nerve sheath and incision of posterior longitudinal ligament over the protruded cartilage. C, diagram of protrusion. D, removal of protrusion (C and D are modified from Naffziger and Boldrey (16).)

There is still much controversy regarding the wisdom of performing spinal fusion at the time of removal of a protruded lumbar intervertebral disc. It is the authors' considered opinion that spinal fusion should not be done at this time. The majority of patients will obtain complete relief from removal of the disc although some troublesome low-back pain may persist when weightbearing is resumed. In some instances, unfortunately, severe low-back pain and even occasionally a recurrence of sciatica will be experienced. In these patients, spinal fusion should be carried out at a later time. It is not considered wise by us to perform fusion in all cases,

played a part. The protein content of the spinal fluid may or may not be elevated.

In doubtful cases, helpful confirmation can be obtained by myelography with the use of pantopaque as a radiopaque medium and careful fluoroscopy on a tilt-table aided by spot films. Myelographic results require experienced interpretation and may be deceptive.

Operative treatment of the intervertebral disc syndrome should be undertaken: 1, when the patient fails to obtain complete relief from conservative orthopedic measures such as bed rest, flexion exercises, and hydrotherapy; 2, when repeated attacks have occurred.

At operation, the incision should provide for exploration of both the fourth and fifth lumbar interspaces in all instances. In thin individuals, about 15 cm. is an adequate length. The muscles are separated from the spines and laminae only on the affected side. On the other side, the deep fascia is incised and the muscles separated only sufficiently to permit a self-retaining retractor to be placed (or a single deep angled retractor may be used only on the affected side). The spines are not removed. With a pointed knife, the ligamentum flavum is incised along the lower lamina of the space to be explored. The ligament is then seized with a Kelly clamp and elevated as its excision is continued in a rectangular fashion, great care being taken not to nick the dura (Fig. 18-8A). Thus the ligament is removed from between the two laminae, providing a small window through which the intervertebral space should first be inspected. This is done by retracting the dura and the emerging nerve root medially. In most instances, if a protrusion is present it will be encountered at once as a smooth, white, rubbery dome which may have displaced the nerve root either laterally or medially. If no protrusion is present, the posterior longitudinal ligament over the disc will be smooth and it will not have the soft rebounding consistency when palpated with an instrument. In this case, nothing further should be done at this interspace and the same exploration should be carried out of the other exposed disc.

If, however, a protrusion is encountered, it is usually wise to remove a narrow, semicircular margin of the laminae above and below the interspace with a Kerrison punch in order to obtain a more adequate exposure (Fig. 18-8A). Protruding fragments of the ligamentum flavum are also removed and the dura and nerve again retracted. Considerable difficulty may be encountered with the thin-walled epidural veins, and this should be handled by packing thin strips of cotton above and below and subsequently by the application of gelatin sponge or fibrin foam. When the surface of the protruded cartilage is revealed, the posterior longitudinal ligament is incised in cruciate fashion with a pointed knife (Fig. 18-8B). The fragmented and sequestrated fibrocartilage will usually protrude as though under pressure and sometimes will almost deliver itself (Fig. 18-8C). It is seized with a pituitary rongeur and pulled out (Fig. 18-8D). It must always be remembered that there may be, and usually will be, several such fragments and one should never be content until all free tissue of the nucleus pulposus has been removed. It is wise to use a small curet in freeing remaining fragments but great care should be exercised in so doing not to penetrate the anterior disc wall.

After the control of bleeding from the epidural veins, the retractor is withdrawn and the wound falls together nicely. It is closed in layers as already described with interrupted silk.

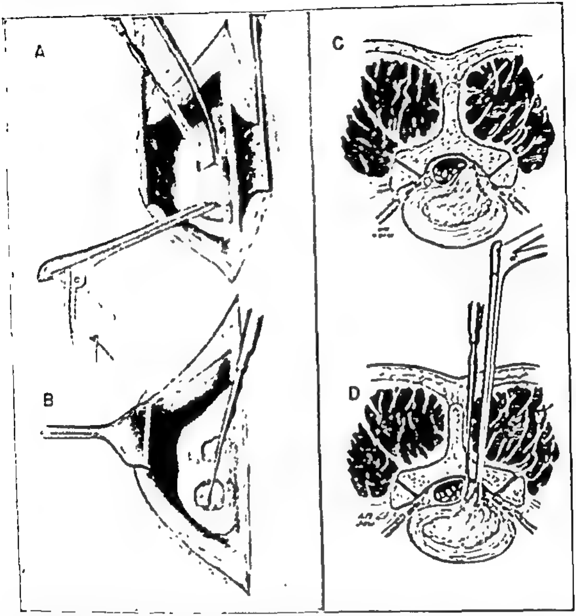

Fig 18-8 Removal of protruded intervertebral disc. A, excision of ligamentum flavum (above), and enlargement of interlaminal opening (below) B, retraction of dura and nerve sheath and incision of posterior longitudinal ligament over the protruded cartilage C, diagram of protrusion D, removal of protrusion. (C and D are modified from Naffziger and Boldrey (16).)

There is still much controversy regarding the wisdom of performing spinal fusion at the time of removal of a protruded lumbar intervertebral disc. It is the authors' considered opinion that spinal fusion should not be done at this time. The majority of patients will obtain complete relief from removal of the disc although some troublesome low-back pain may persist when weightbearing is resumed. In some instances, unfortunately, severe low-back pain and even occasionally a recurrence of sciatica will be experienced In these patients, spinal fusion should be carried out at a later time It is not considered wise by us to perform fusion in all cases,

played a part. The protein content of the spinal fluid may or may not be elevated.

In doubtful cases, helpful confirmation can be obtained by myelography with the use of pantopaque as a radiopaque medium and careful fluoroscopy on a tilt-table aided by spot films. Myelographic results require experienced interpretation and may be deceptive.

Operative treatment of the intervertebral disc syndrome should be undertaken: 1, when the patient fails to obtain complete relief from conservative orthopedic measures such as bed rest, flexion exercises, and hydrotherapy; 2, when repeated attacks have occurred.

At operation, the incision should provide for exploration of both the fourth and fifth lumbar interspaces in all instances. In thin individuals, about 15 cm. is an adequate length. The muscles are separated from the spines and laminae only on the affected side. On the other side, the deep fascia is incised and the muscles separated only sufficiently to permit a self-retaining retractor to be placed (or a single deep angled retractor may be used only on the affected side). The spines are not removed. With a pointed knife, the ligamentum flavum is incised along the lower lamina of the space to be explored. The ligament is then seized with a Kelly clamp and elevated as its excision is continued in a rectangular fashion, great care being taken not to nick the dura (Fig. 18-8A). Thus the ligament is removed from between the two laminae, providing a small window through which the intervertebral space should first be inspected. This is done by retracting the dura and the emerging nerve root medially. In most instances, if a protrusion is present it will be encountered at once as a smooth, white, rubbery dome which may have displaced the nerve root either laterally or medially. If no protrusion is present, the posterior longitudinal ligament over the disc will be smooth and it will not have the soft rebounding consistency when palpated with an instrument. In this case, nothing further should be done at this interspace and the same exploration should be carried out of the other exposed disc.

If, however, a protrusion is encountered, it is usually wise to remove a narrow, semicircular margin of the laminae above and below the interspace with a Kerrison punch in order to obtain a more adequate exposure (Fig. 18-8A). Protruding fragments of the ligamentum flavum are also removed and the dura and nerve again retracted. Considerable difficulty may be encountered with the thin-walled epidural veins, and this should be handled by packing thin strips of cotton above and below and subsequently by the application of gelatin sponge or fibrin foam. When the surface of the protruded cartilage is revealed, the posterior longitudinal ligament is incised in cruciate fashion with a pointed knife (Fig. 18-8B). The fragmented and sequestrated fibrocartilage will usually protrude as though under pressure and sometimes will almost deliver itself (Fig. 18-8C). It is seized with a pituitary rongeur and pulled out (Fig. 18-8D). It must always be remembered that there may be, and usually will be, several such fragments and one should never be content until all free tissue of the nucleus pulposus has been removed. It is wise to use a small curet in freeing remaining fragments but great care should be exercised in so doing not to penetrate the anterior disc wall.

that the acute cord compression which it produces may produce irreversible loss of function. This is presumably due to advancing thrombosis of spinal veins with resultant necrosis of cord substance.

The operation consists of a simple, limited decompressive laminectomy with drainage of the abscess. It must not be forgotten that the abscess may be anterior and may not be encountered when the laminae are first removed. The dura should be retracted until the abscess is entered. Under no circumstances should the dura be opened. A Penrose drain should be inserted into the abscess cavity and the wound closed about it. It may be withdrawn slowly as the wound heals from the bottom. Vigorous penicillin and sulfonamide therapy should be employed.

Chronic epidural abscesses are sometimes encountered. Although not so urgent, they also require operative drainage.

Tuberculosis of the Spine with Compression of the Cord. In some cases of Pott's disease, the spinal cord is compressed by a mass of granulation tissue within the spinal canal in the presence of the acute kyphos so often present as the result of collapse of a vertebral body. In the majority of instances, relief of cord symptoms will follow prolonged hyperextension on a Bradford frame and operative decompression is unnecessary. When cord compression persists in spite of such measures, operation should be performed.

It should consist of open decompressive laminectomy with removal by blunt dissection of the large masses of tuberculous granulation tissue. The wound should then be closed tightly without drainage since otherwise a tuberculous sinus is very likely to develop. Absolute rest in hyperextension for a long period after operation is essential.

Evacuation and drainage of a paraspinal tuberculous abscess communicating with an intraspinal tuberculous infection may relieve the symptoms of cord compression. Vigorous treatment with the appropriate antibiotics is essential.

Chronic Adhesive and Cystic Arachnoiditis. Surgical therapy is rarely, if ever, required in acute leptomeningitis but the formation of chronic arachnoidal scarring and adhesions and sometimes of arachnoidal cysts following recovery from a severe and extensive meningitis is not uncommon. Syphilitic meningitis is said to be responsible for the condition in about 30 per cent of cases. If the fibrosis resulting from this process is localized and severe, the cord may be compressed with the presentation of a localized clinical picture suggestive of cord tumor. There will usually be a block of cerebrospinal fluid circulation and myelography will show an irregular, patchy partial obstruction below the uppermost level with final complete obstruction where the constriction is greatest.

If the clinical picture is sufficiently localized to suggest that the lesion may be confined to a small area of the cord, operative interference is indicated.

At operation, when the dura is opened, dense adhesive bands will be found. The dura may be adherent to the surface of the cord and will have to be dissected away by a fine, blunt dissector or sharp knife with great caution. It is often possible to free constriction of the cord in this manner

simply on the basis of the possibility that it may be necessary in a few cases. Possible exceptions to this general policy are individuals with spondylolisthesis and those whose occupation necessitates extremely heavy lifting or other severe backstrain.

Patients who have a simple removal of a protruded lumbar intervertebral disc may be up and out of the hospital within a week following operation but should avoid lifting and strain for several months.

Cervical Region. In the cervical region, protrusion of the intervertebral disc occurs at the fifth, sixth, or seventh intervertebral spaces, most commonly at the sixth. They may protrude in the midline so extensively as to produce compression of the cord but usually there is a small protrusion extending laterally into the intervertebral foramen and compressing the emerging nerve root as in the lumbar region. In longstanding cases, this protrusion may be retracted, fibrosed, or even calcified but may still produce symptoms. In addition to following the distribution of the nerve root involved, the pain is usually referred to the scapular region and sometimes to the precordial area (being occasionally mistaken for angina pectoris). The pain is worse when the patient is sitting or standing, usually is relieved by lying down, may be exacerbated by pressure upon the top of the head or bending the head toward the affected side. It is often relieved by traction on the head. Halter traction or even a Thomas collar should be employed as conservative methods before operative treatment is undertaken.

Oblique roentgenograms of the cervical spine to show the intervertebral foramina are sometimes of value in demonstrating partial obstruction of a foramen by the protrusion. Myelography is of value but should be avoided in most cases because of the likelihood of entrance of the opaque medium into the cranial cavity and sometimes into the ventricles.

The *operative treatment* is similar to that in the lumbar region except that a more extensive unilateral laminectomy is usually necessary and removal of bone far laterally to decompress the intervertebral foramen may be demanded. This is particularly true in the case of the calcified protrusions lying far laterally in the foramen. In these cases the decompressive procedure alone will usually give relief of symptoms.

INFLAMMATORY DISORDERS

Epidural Abscess. Acute spinal epidural abscess is a fulminating disorder which may produce irreparable cord damage with great rapidity. The exact mechanism of its production is not known but it frequently follows relatively minor superficial infections of the skin overlying the spine, usually of staphylococcic origin. However, the lesion may be secondary to a focus of infection elsewhere in the body Osteomyelitis of a vertebra may or may not be present.

The presence of nerve root pain, with rapidly advancing evidence of cord compression at the level of the pain, fever, leukocytosis and the existence of a focus of infection constitute the classic clinical picture.

Epidural abscess is an acute surgical emergency because of the fact

progressive *predictable* loss of function of the spinal cord *below a given level.* The cerebrospinal fluid shows partial or complete blockage on Queckenstedt test and the protein content of the fluid is usually greatly increased. Where the blockage is complete and of very long standing, the fluid may be yellow and may coagulate on standing (Froin syndrome). In addition to possible destructive lesions of the vertebrae, the pedicles seen in the anteroposterior view may be eroded at the site of the tumor or may be more widely separated than normal as evidence of distention of the spinal canal.

In contrast to the dark picture of injuries of the spinal cord, many cord tumors present a very favorable prognosis following removal and recovery may be rapid and dramatic. The spinal cord can tolerate slowly developing compression to a point where it becomes a thin ribbon with amazing return of function after relief of compression.

It is well to remember that the cord seems to have a threshold of compressibility in some instances. In such cases, longstanding compression which comes on very gradually may produce no symptoms whatever until the final limit of compressibility is reached. At such a time, the onset of complete paralysis may come suddenly and may be misinterpreted as the result of injury or development of epidural abscess.

Extradural Tumors. Although lipomas, chordomas, fibrosarcomas, epidermoid and other tumors may occur in or infringe upon the spinal canal, the great majority of extradural neoplasms have their origin in the bone of the vertebral column. Of these, metastatic carcinoma (particularly from the prostate, kidney, breast or uterus) and myeloma are the most common. Benign giant cell tumors and Ewing's sarcomas are sometimes encountered and in the cervical region occurs a peculiar lesion characterized microscopically by both osteoplastic and osteoblastic reaction, somewhat resembling Paget's disease.

In most instances, if a known focus of primary malignant disease is present and a destructive lesion of the bone of the spine is demonstrable in roentgenograms, radiation therapy should be given to the spine. Metastases from *carcinoma of the breast* are often surprisingly radiosensitive. With prostatic carcinoma, administration of stilbesterol or orchidectomy may produce a surprising recession of metastatic lesions.

On the other hand, if the lesion does not respond to radiation or other methods, and if the patient's life expectancy exceeds a few months, laminectomy with removal of sufficient tumor to secure adequate decompression of the cord may be indicated.

At operation, vascular neoplastic tissue may completely encircle the dural sac but no effort should be made to remove more than that portion which can be easily exposed and taken away without traumatizing the cord. It is essential to carry the exposure well above and below the portion of the tumor which is producing compression and it should be possible to pass an angled instrument or catheter up and down the canal outside of the dura without obstruction, if the laminectomy is sufficiently extensive.

As a rule, the tumor tissue can be removed by blunt dissection or even by suction. Bleeding is likely to be annoying and should be controlled by electrocoagulation (care being taken not to burn nerve roots or injure the

to such an extent that symptoms will completely or nearly completely disappear but the adhesions are prone to reform and recurrence of symptoms may take place after varying intervals.

In some instances, the adhesions have resulted in the formation of an arachnoidal cyst which produces cord compression. Opening and drainage of this cyst with breaking up of its walls may result in permanent cure.

Abscess of the Cord. In rare instances, a general or localized meningitis may result in formation of an intrinsic abscess in the cord substance. Such abscesses if they develop slowly may present an appearance which suggests almost complete destruction of the cord but may result in surprising recovery if they are evacuated early and the infection controlled by chemotherapeutic measures.

At operation, a localized swelling of the cord may be present. More commonly, the dura is adherent and when separated, results in the oozing of pus from a cavity in the cord substance, which has been opened by the dissection. The contents of the cavity should be gently irrigated away after walling off of the exposed area by gentle placement of cotton pledgets above and below. The dura should be closed tightly and intratracheal penicillin therapy promptly instituted and continued for some days. A small rubber tissue drain should be inserted into the wound outside of the dura and removed gradually over a period of several days.

Transverse Myelitis. The term transverse myelitis is very loosely used and has come to be employed to describe any complete transverse loss of cord function which is not due to a recognizable gross lesion. In the majority of instances, the disorder is due to multiple sclerosis. However, in the absence of evidence of this disease elsewhere in the nervous system and in the presence of a clean-cut localizing picture it may be impossible to arrive at a conclusive diagnosis and the neurosurgeon may be faced with the necessity of carrying out an exploratory laminectomy in order to avoid overlooking the presence of a small tumor. If, when the dura is opened, no evidence of tumor is present in the exposed area, a tiny soft rubber catheter should be passed upward and downward in the spinal canal to be sure that the localization has not been mistaken. If no obstruction is encountered, the wound must be closed without further ado. In rare instances, the small sclerotic plaques of multiple sclerosis may be visible on the surface of the cord. The cord should never be incised for possible intrinsic lesions in the absence of definite and gross localized enlargement.

NEOPLASMS

Tumors which compress the spinal cord may be extradural, intradural but extramedullary, or intramedullary. It is not always possible to distinguish among the three types. In general, however, it may be said that extradural tumors usually are accompanied by roentgenographic evidence of bone destruction. Extramedullary but intradural tumors nearly always cause severe nerve root pain without destructive lesion of bone and intramedullary tumors are rarely accompanied by root pain.

In all instances, the clinical picture is usually that of a very slowly

the arachnoidal and vascular connections which may be holding it in place and separating it with great gentleness from the adjacent spinal cord. As soon as the initial line of cleavage has been opened, one or more silk stitches should be placed through the capsule and substance of the tumor and used to make gentle traction in order to deliver the lesion as it is freed from its bed (Fig. 18-9C). Occasionally, division of a posterior root will be necessary, in order to avoid damaging traction upon it.

In the case of meningiomas, the stalk of attachment should be the last aspect of the lesion to be attacked and it should be freed and delivered in so far as possible in all of its remaining portions. Its vascularity will be considerable and it is important to isolate and control each individual blood vessel which bridges the gap between cord and tumor or dura and tumor. Any vessels in close proximity to the cord should be occluded with silver clips and divided between such clips. Those which are not close to the cord may be very carefully coagulated. Treatment of the dural attachment must depend on its exact location. If the origin of the tumor is from the free posterolateral portion of the dura, the dural attachment should be excised by encirclement and removed with the tumor (Fig. 18-9C). If the origin of the tumor is anterior or anterolateral, the tumor which has previously been freed at all other points should be forcibly dissected away by blunt dissection, leaving the area of attachment with its adherent tumor stalk. With the main mass out of the way, the dura may then be removed with sufficient room to take care of bleeding from the epidural veins which is inevitable in such cases.

In some instances the tumor will have invaded through the dura and an epidural mass of tumor will also be present. It is best in such cases to divide the dura from the side down to a point close to the stalk and then to encircle it by a dural incision which removes the stalk of attachment and any epidural portion of the lesion at the same time.

Occasionally, the epidural portion will be much larger than anticipated and will extend far into the intervertebral foramen. It should, of course, be dissected out if possible, but this occasionally may be out of the question, in which case the tumor must be cut across and its extraspinal portion removed by another approach at a different time (this is particularly true of the hour-glass tumors which extend into the mediastinum anteriorly).

Care should be taken to get as little blood as possible into the spinal canal. Intradural vessels should be controlled by gentle pressure during the stage of tumor removal and subsequently by the application of gelatin sponge or fibrin foam soaked in thrombin or of pledgets of muscle.

If the dural defect is anterior or anterolateral, it may be left open. On the other hand, if it is posterolateral, it should be covered by fibrin *film* or a fascial transplant secured from the deep fascia in the superficial portions of the wound.

The neurofibromas are usually more easily dealt with and can be completely removed without any dural defect by the simple expedient of dividing the attached nerve root proximally and distally, securing all vascular *connections* as already described and delivering the tumor with great care not to damage the spinal cord

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Intradural Extramedullary Tumors. With rare exceptions, these tumors are meningiomas arising from the arachnoid (or possibly the dura) or neurofibromas arising from the sheaths of nerve roots. Both types of tumor are encapsulated except for their points of origin. Both grow very slowly and compress the cord from the outside, without invading it (Fig. 18-9B). The operative removal of tumors of both types is identical except that the nerve root from which a neurofibroma arises must be divided proximal and distal to the lesion.

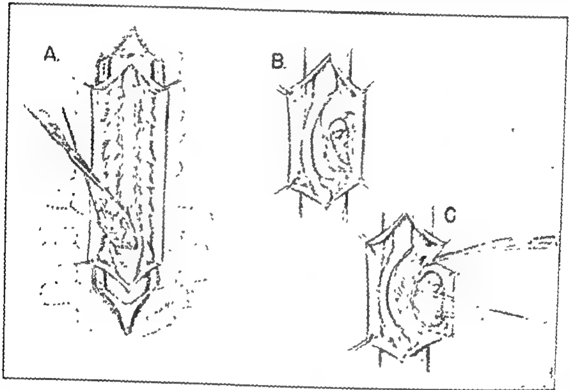

Fig 18-9 Removal of cord tumors A, intramedullary tumor B, appearance of extramedullary tumor (meningioma) C, removal of meningioma with its dural attachment.

When the laminectomy has been completed and the exposed area of dura isolated by application of sheets of moist cotton, it will frequently be possible to locate the tumor by inspection or palpation or both. A localized enlargement and firmness of the dural sac clearly indicate the underlying lesion. By this demonstration of the location and approximate extent of the tumor, it is possible to be certain that the laminectomy is sufficiently extensive before opening the dura

The dura should be opened at the upper end of the incision. The opening should be carried caudally in the midline, care being taken not to damage the cord or tear vessels on the surface of the tumor in passing over it. All neurofibromas and most meningiomas lie lateral or anterolateral to the cord. This means that the cord must be retracted ever so gently. This should rarely be done by an actual retractor but by the process of dissection with a small blunt dissector in the early stages and subsequently by the process of delivery of the tumor en masse from its attachment.

It is best to start the freeing of the tumor at one end, carefully severing

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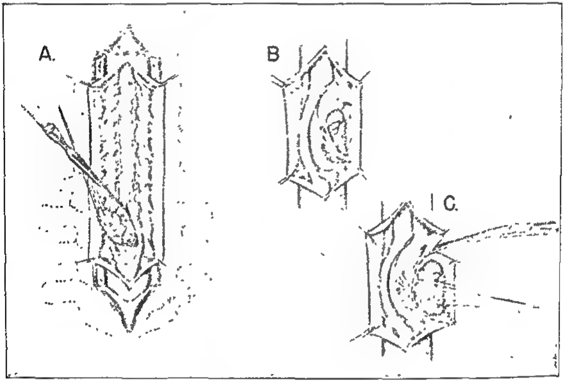

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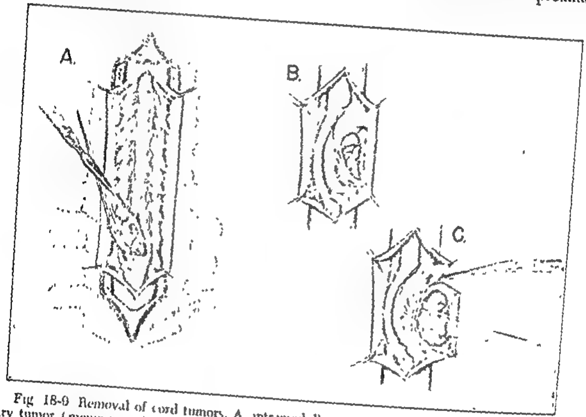

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It is best to start the freeing of the tumor at one end, carefully severing

section with a small, blunt instrument and delivered in its entirety without greatly increasing the damage to the cord.

Often, the tumor extends for a considerable length up and down the cord and a very extensive laminectomy will be necessary. It should be remembered that removal of such tumors is useless unless the operation is made sufficiently extensive to carry out as radical a procedure as possible.

In some instances, of course, the lesion is diffuse and fiber tracts of the spinal cord can actually be demonstrated to run through it. There is a general enlargement of the cord substance without line of demarcation between tumor and nerve tissue. In these cases, removal is hopeless and should be abandoned without increasing the damage which the lesion has already produced. This is particularly true in the cervical region where even slight increase in damage may result in fatal respiratory paralysis.

As in the case of other cord lesions, the dura should not be closed until all bleeding, however trivial, has been completely controlled.

Syringomyelia. This condition is not a true neoplasm but may be considered here for convenience because of the similarity of its symptoms to those produced by tumors.

Syringomyelia is a congenital anomaly of the central canal of the spinal cord. An isolated segment of this canal seemingly becomes blocked and gradually accumulates fluid within its cavity assuming a slowly progressively larger size with the accumulation of fluid until a cyst of sizable proportion, which compresses the surrounding cord substance, is produced.

Such syringomyelic cysts may occur in any portion of the spinal cord but are far more common in the cervical region than elsewhere. Because of their central location, their principal early damage is to adjacent central areas and particularly to the crossing commissures containing the pathways of pain and temperature for the corresponding level of the cord. This results in the well-known dissociation of sensation in which there is a zone of retention of normal tactile sensation and loss of pain and temperature sense. There may also be disturbance of trophic nerve supply and various spontaneous paresthesias, including pain, burning and itching.

As the lesion becomes more extensive, the entire spinal cord is compressed with the local anterior grey horns being involved first and the peripheral projection pathways last of all.

Thus the typical patient with cervical syringomyelia has atrophic, sometimes contracted fingers, which have been burned or otherwise injured, and below the level of the upper extremities spastic paralysis and loss of sensation of varying degree.

Syringomyelia cannot be cured surgically but symptoms may be alleviated for a long period by evacuation of the cyst and subsequent irradiation therapy. Surgically, this procedure is carried out as for intramedullary cord tumors by a posterior midline incision of the cord. No attempt should be made to remove the cyst lining but it should of course be left as wide open as possible.

Occasionally, one of the extramedullary tumors attains considerable size by growing in a longitudinal direction in the spinal canal. The surgeon is always tempted to perform a rapid enucleation of these lesions but cord damage is almost certain to follow such a policy. The most painstaking exercise of care and patience will be rewarded by a seemingly miraculous recovery and no precaution must ever be neglected to avoid the slightest trauma to the cord substance.

Intramedullary Tumors. Nearly all intramedullary neoplasms of the spinal cord are either ependymomas arising from the lining of the central canal or astrocytomas arising from the glial supporting tissue of the spinal cord substance. These lesions do not have the favorable prognosis enjoyed by extramedullary tumors since they are essentially invasive and since the substance of the cord must be traversed in order to remove the tumor. Both ependymomas and astrocytomas may have a sort of false encapsulation and in favorable cases both may be removed successfully with long periods of remission of symptoms. In addition, ependymomas tend to have some degree of radiosensitivity and following removal can be prevented from recurring for long periods by means of radiotherapy.

Clinically, intramedullary tumors are likely to produce complete blockage of cerebrospinal fluid flow somewhat later in the development of symptoms than are extramedullary tumors. Furthermore, as already stated, they are much less likely to cause nerve root pain.

At operation, the tumor can often be detected before the dura is opened as in the case of extramedullary tumor because of the fusiform enlargement of the cord which takes place. When the dura is opened, the cord is seen to be swollen and at times a discoloration can be seen resulting from the darker tumor substance showing through the thinned cord tissue.

Regardless of the location of the tumor, incision of the cord should be made in the posterior midline. This may necessitate division of some of the small tortuous vessels lying in the pia mater on the posterior surface of the cord Bleeding from these is never serious and the surgeon should never be stampeded into coagulating or clamping these vessels. They should be controlled by the application of a tiny pledget of cotton with very gentle pressure. Later in the procedure, after removal of the tumor, this can be replaced with a small fragment of gelatin sponge soaked in thrombin

The incision in the cord should be made with a very sharp, pointed knife (never with the electrosurgical current). Once the incision in the pia is made, a small blunt dissector may be used to carry the incision more deeply until the surface of the tumor is reached. The lesion will usually give the appearance of encapsulation and it is frequently sufficiently firm to be pulled upward by means of traction sutures as in the case of extramedullary tumors (Fig. 18-9A). In other cases, gentle dissection and elevation of the tumor on an angled instrument which is carefully thrust under it will be necessary. In rare instances, the tumor will have no clear line of demarcation and will be so soft as to be largely removable by very careful suction.

In most instances, the lesion can be stripped out by meticulous dis-

lateral surface (opposite to the side of the pain) is exposed, a sharp-pointed knife is plunged through the pia mater exactly through the anterior attachment of the dentate ligament. With a rotating movement, it is carried through the pia and cord substance in an anterior and lateral direction to emerge through the level of the exit of the anterior root (Fig.

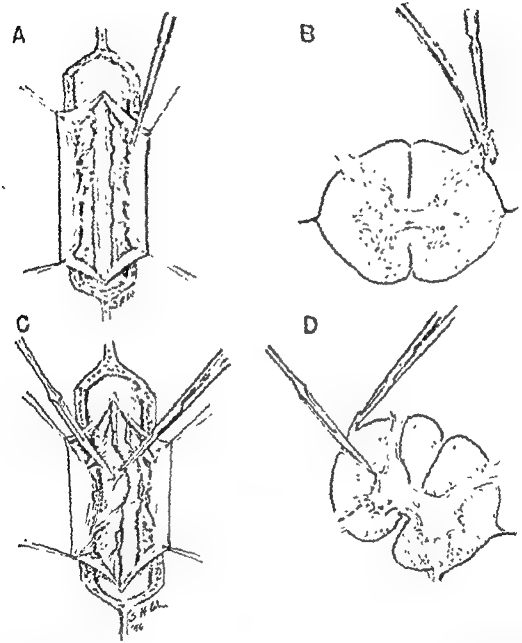

Fig 18-10 Operations for the relief of pain A and B posterior rhizotomy C and D, anterolateral chordotomy (see also Fig 18-2 F) The cord is rotated by traction upon the dentate ligament.

18-10C and D) In order to relieve pain, at a relatively high level in the trunk (such as tabetic crises) the section should be carried to a depth of 5 mm. which will result in section of a portion of the lateral horn of the grey matter For pain in lower cord segments, a section 3 mm. in depth will be sufficient.

Although it is usually quite satisfactory to carry out the entire section

THE RELIEF OF INTRACTABLE PAIN

When pain is intolerable and cannot be relieved by removal of its cause, it is sometimes necessary to divide the pathways in the nervous system which conduct the pain in order to make life bearable for the patient. The pain of pelvic carcinoma, the visceral crises of tabes, the occasionally intractable pain of postherpetic neuralgia and similar conditions must be so treated.

Pain in spinal nerves confined to one or two segments may be treated by alcohol injection in the paraspinal region. Recently, the pain of causalgia has been treated extensively by sympathectomy. However, for pain in an extensive area not amenable to such procedures, there are two operations within the spinal canal which may be exceedingly valuable.

Anterolateral Chordotomy. Section of the anterolateral spinothalamic tract in which virtually all painful impulses are conducted in the side of the spinal cord opposite to the source of the pain is an exceedingly valuable procedure which makes life worth living for many patients. The procedure destroys the sense of pain and temperature beginning at a level several segments below the level of section. Tactile and position sense are not disturbed and no unpleasant after-effects are likely to occur if the procedure is carried out properly on one side.

However, in the case of bilateral chordotomy particularly when a deep section is made, paralysis of the bladder may occur and is sometimes permanent. This may be avoided in some instances by making the section at slightly different levels on the two sides.

The operation should be carried out high in the dorsal region (that is, at the level of the second dorsal vertebra) in most instances although pain which is confined to the lower segments of the spinal cord may be relieved by spinothalamic tract section at a lower level. It is probably wiser, however, to do all chordotomies in the upper thoracic region and to vary the depth of the section according to the level of analgesia to be desired. This is possible since the distribution of pain-carrying fibers in the spinothalamic tract is such that the lowermost spinal segments are represented in the most superficial portions of the spinothalamic tract whereas those pain fibers which have just entered the spinal cord lie most deeply in the tract. There is increasing evidence that chordotomy carried out in the high cervical region is quite safe and may be done bilaterally. The level of analgesia may thus be brought much higher.

The operative procedure is a delicate one, but quite simple in experienced hands After the dura is opened, one of the filaments of the dentate ligament extending between the cord and the dura should be located and picked up with a mosquito forceps. With a pointed knife, the ligament is divided on the dural side of the forceps and the ligament thus grasped by the clamp is used for a dual purpose. first, for rotation of the cord by traction upon the clamp and secondly, as a landmark to identify the posterior limits of the spinothalamic tract. This is exceedingly important because any section of the cord posterior to this point is very likely to injure the pyramidal tract and result in paralysis of the homolateral lower extremity.

When the cord has been rotated away from the dura so that its antero-

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with the pointed knife, it may be done even more accurately with an angled chordotomy knife, the precise length of whose blade is known. Chordotomy knives can usually be used successfully only after division of the pia by a pointed blade.

If the procedure is to be bilateral, the exposure should include at least two cord segments so that the chordotomy may be done at different levels on the two sides.

There may be a little difficulty with small vessels of the pia which have been divided but these are usually controlled quite easily by gentle pressure with moist cotton or by application of gelatin sponge and thrombin.

Posterior Rhizotomy. Section of posterior spinal roots which was formerly employed with considerable frequency is a relatively rare procedure now. It should never be employed in the cervical or lumbar areas and is useful on the thoracic roots only when the patient's pain is confined to a relatively few segments and can be accurately localized. When it is to be done, the selected filaments of posterior roots are elevated on a blunt hook and divided with scissors (Fig. 18-10A and B). The procedure may be carried out under local anesthesia in order to have the cooperation of the patient in locating the pain-bearing roots. Pain will be readily produced by the slightest traction upon a posterior root.

MISCELLANEOUS PROCEDURES

In addition to the well recognized operations and indications for their use already described, several additional procedures have been advocated for special uses but have not enjoyed extensive employment.

Anterior Root Section for Hypertension. Page and Heuer have advocated very extensive section of thoracic anterior roots for obliteration of preganglionic sympathetic impulses to the thoracic and abdominal distributions This is an exceedingly formidable procedure involving a lengthy laminectomy from the upper dorsal to the upper lumbar region with section of nearly all of the thoracic anterior roots. It has not been widely employed and is now superseded by the extraspinal thoracolumbar sympathectomy.

Extrapyramidal Tract Section. Putnam has devised the procedure of section of the anterior columns of the spinal cord for the purpose of eliminating extrapyramidal impulses in cases of severe, uncontrollable tremor and spasticity.

This procedure must be carried out in the high cervical region and carries a very considerable risk of respiratory paralysis. Its true usefulness cannot yet be fully evaluated

Anterior Rhizotomy for Spasticity. For relief of the extreme degree of spasticity, particularly of the adductor muscles and of the very troublesome mass reflexes which occur in many cases of spinal cord injury (whose paralysis is already hopeless), Munro has advocated section of anterior roots which, of course, converts the spastic paralysis into a flaccid one. Years ago, Foerster showed that this type of spasticity could be eliminated by section of posterior roots but neither procedure has as yet been widely employed.

Alcohol Injection of Branches of the Trigeminal Nerve. Alcohol injection of one or more of the branches supplying the painful area of the face provides a means of temporary relief until the nerve regenerates, which it always does. Since the pain more commonly occurs in the lower half of the face, either the maxillary or mandibular divisions, or both, are injected at the points of their emergence from the skull. The more peripheral infra-orbital or the mental branches can sometimes be injected at their respective foramina if the pain is localized in the limited areas supplied by these nerves. Similarly, the supra-orbital branch of the first division of the trigeminal can be injected when the pain occurs in the forehead. The technic for injection of these various nerves is described in standard texts dealing with local anesthesia. It must be remembered, however, that it is one thing to infiltrate procaine in the general region of a nerve for brief anesthesia and another to interrupt nerve function by alcohol. In the latter case the injection must be made directly into the nerve or immediately about it with not more than 1.0 ml. of absolute alcohol.

The relief from alcohol injection may last for many months, though the average is less than a year and subsequent injections are often less effective. Many surgeons feel that even though alcohol injection provides but temporary benefit there is an advantage to the procedure in that the patient learns the feeling of numbness which he will have to accept as permanent if the nerve is divided intracranially. But the degree of numbness is not usually the same in the two procedures and the injection of alcohol is not without considerable pain and occasional complications of its own, resulting particularly from accidental infiltration of orbital tissues, eustachian tube or parapharyngeal structures.

Alcohol Injection of the Gasserian Ganglion. Permanent relief of tic douloureux may sometimes result from injection of the gasserian ganglion. The needle is introduced below the zygoma and directed to the foramen ovale. After the third division of the nerve is encountered the needle point is advanced a little farther where it should enter the gasserian ganglion. Injection of a small amount of alcohol should destroy the ganglion cells and prevent regeneration of the nerve which occurs with more peripheral nerve injections. Unfortunately the method is unsafe even with the most careful technic for if enough is injected to assure complete destruction of the ganglion the alcohol may enter the subarachnoid space, seriously damaging the brain stem and various cranial nerves. The procedure is infrequently employed in the present day because of its dangers and the improvement in other methods.

Avulsion of Supra-orbital and Infra-orbital Nerves. Avulsion of the supra- or infra-orbital nerves because of its greater certainty and longer lasting effect over alcohol injections is sometimes employed. There may be relief for four or five years, but the results are not always reliable and return of pain is to be expected eventually in most cases. The supra-orbital nerve is exposed at its foramen by an incision through the medial third of the brow. The infra-orbital nerve is exposed at its foramen by strong retraction of the upper lip after an incision is made at the line of juncture between the upper lip and gum.

For best results from each of these operations care must be taken to

19

LESIONS OF THE CRANIAL NERVES

Bronson S. Ray

Certain cranial nerves may require surgical treatment when there is intrinsic disease of the nerves themselves or of structures supplied by them. The first six cranial nerves with exception of the trigeminal do not fall in this category. Of the remaining nerves, the trigeminal most commonly requires some form of surgical intervention.

TRIGEMINAL NERVE

Tic douloureux (synonyms: trigeminal or trifacial neuralgia) is a painful affliction of the face which has special characteristics that distinguish it from all other facial pain. Although the disease has been recognized for centuries, the French name of tic douloureux given by André in 1756 is most appropriate. The salient properties of the pain constitute a triad: 1, the pain is limited to all or a part of the area supplied by the sensory root of the trigeminal nerve, 2, it is paroxysmal and of short duration; and 3, it is induced by stimulation of the nerve endings (trigger zones).

The pain usually develops between the ages of 40 to 60 years, though occasionally it makes its initial appearance in the earlier or later decades of life. Men and women are affected equally. The etiology of the disease is unknown, but its occurrence as an affliction principally in adult and elderly life suggests that it is related to vascular changes or some aging process that affects the nerve. It is not expected that there will be found any abnormal neurologic signs in tic douloureux. If there are any accompanying signs such as sensory impairment or muscular palsy of the face or impairment of hearing on the side of the pain an intracranial tumor in the cerebellopontile angle usually exists. Occasionally an acoustic neurinoma, cholesteatoma or meningioma lying adjacent to the trigeminal nerve in this angle will produce facial pain, indistinguishable from tic douloureux.

Although there are periods of spontaneous remission which may last many months, there is rarely, if ever, failure of return of pain in tic douloureux and usually successive exacerbations can be expected to become more severe and lasting.

A great variety of nonsurgical treatment of tic douloureux has been proposed over a period of years. Some of the treatments have been based solely on empiricism such as inorganic iron ingestion, or on anesthetic effects as occur with inhalation of trichlorethylene, or on vasodilator effects such as occur with the recently advocated concentrated vitamin B. But none of these can be expected to result in more than temporary benefit. The pain can be relieved with certainty only by interruption of the trigeminal nerve somewhere along its pathway.

or supine position. Many surgeons prefer local anesthesia and the majority place the patient in a sitting position; however, the author usually employs ether anesthesia and places the patient on his back with the head turned to one side. The incision, about 6 cm. in length, is made vertically just in front of the ear, the lower end of the incision approximating the upper margin of the zygoma (Fig. 19-2). The soft tissues including skin, temporal fascia and muscle and the periosteum, all of which have been incised along the same line, are reflected from the temporal bone and held apart with a self-retaining retractor. The temporal bone thus exposed is perforated and a rounded window about 5 cm. in diameter is rongeured away, the lower margin of which extends to the floor of the middle fossa. If mastoid cells are entered in the process there is need only to plug them with bone wax.

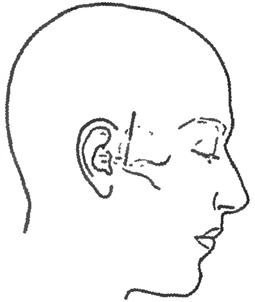

Fig. 19-2. Diagram to show site of incision for approach to posterior root of trigeminal nerve through middle fossa. Stippled area shows approximate amount of bone removed. (Courtesy of Francis Grant.)

Preservation of the intact dura while removing the temporal bone and subsequently in separation of the dura from the floor of the middle fossa is important though often tedious or impossible because of adherence of dura to bone, particularly in the aged. As the dura is separated and retracted from the floor of the fossa the middle meningeal artery is identified at the foramen spinosum and there the artery is divided. It may be tied, clipped or coagulated on the dural side while bleeding in the foramen is controlled by coagulation or plugging with bone wax. Occasionally the middle meningeal artery is nonexistent, very small or placed so that it does not have to be dealt with in exposing the trigeminal nerve.

The first landmark in recognizing the nerve is the mandibular division where it passes through the foramen ovale. As the dura is retracted further it separates from the sheath covering the gasserian ganglion and the sensory root behind it. The posterior margin of the ganglion is identified by the faint pulsation of the cerebrospinal fluid beneath the sheath covering the root and the root is exposed at this point by an incision in the sheath running transverse to the root fibers. The sensory root can usually be pulled forward by a nerve hook and separated from the motor root which lies beneath. Partial or total division of the sensory root can be accomplished

divide all the nerve fibers at the foramen and an effort made to draw out as much of proximal and distal portions of the divided nerve as possible. If pain returns and is still confined to the local area supplied by one of these nerves a repetition of the destruction of fibers at the foramen may postpone the need for a more radical operation.

Rhizotomy: Surgical Interruption of the Sensory Root of the Trigeminal Nerve. Lasting relief of tic douloureux can be obtained by division of the sensory root of the trigeminal nerve, that is, the portion of the nerve that lies between the gasserian ganglion and the brain stem. There are two surgical approaches to the sensory root (Fig. 19-1); one is extradural in the temporal fossa, the other is intradural in the posterior fossa(4).

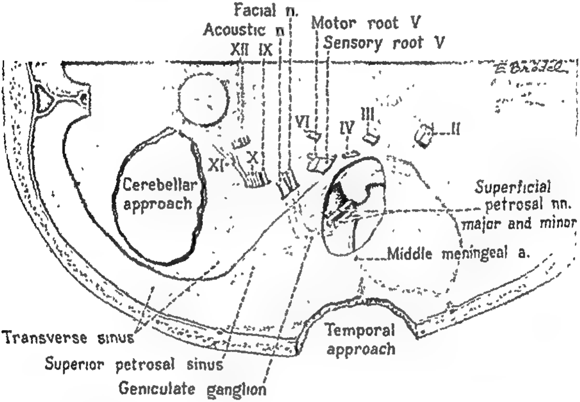

Fig 19-1 Drawing to show the relative positions of the cranial nerves and the two operative approaches.

*If the sensory root is completely divided anesthesia results in all parts of the head and face supplied by the nerve, including the cornea. Since it is desirable to preserve corneal sensation, if possible, and also since pain and trigger zones are limited to the lower part of the face, supplied by the mandibular and maxillary division, in 70 per cent of the patients a partial and selective section of the root is employed. If pain involves the upper part of the face it is usually necessary to perform a complete rhizotomy, thus sacrificing corneal sensation.

While there are advantages and disadvantages to each of the surgical approaches to the sensory root the choice is often arbitrary and dependent on the skill the individual surgeon has developed in one or the other technic. The temporal approach is preferred by most surgeons.

In the *temporal approach to trigeminal rhizotomy*, local or general anesthesia is employed and the patient may be in a sitting, semireclining

both the first and third division areas of the face, but may not always be a safeguard against regeneration of some fibers in the second division.

In the *posterior approach to trigeminal rhizotomy* general anesthesia is preferred and local anesthesia is less appropriate than in the temporal approach. A horizontal position for the patient, either prone or lying on the side opposite the rhizotomy, is safer than the upright position in the majority of elderly patients with tic douloureux because of the loss of cerebrospinal fluid and displacement of remote intracranial structures that accompanies the upright position The incision can be either curved or

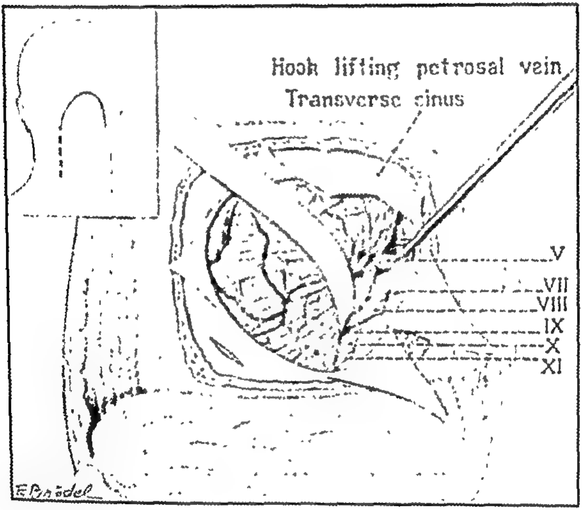

Fig 19-4 Operative approach for exposure of cranial nerves in the posterior fossa of the skull The inset indicates the location of the incision which may be extended down to the mid-line of the neck if cranial nerve section is to be combined with cervical rhizotomy

straight, but the former is preferable in most patients since it insures a less hampered exposure of the occipital bone in its lateral extent just behind the mastoid bone (Fig 19-4) Enough bone is removed in the region beneath the margin of the transverse venous sinus and behind the mastoid cells to permit adequate exposure of the cerebellopontile angle. If mastoid cells are deliberately or accidentally opened they should be plugged with bone wax, and if there is a history of mastoiditis an added protection against wound infection is provided by the reflection of a small dural flap across the opened mastoid cells.

with a sharp knife or simply by lifting up the nerve with a hook until the fibers tear (or avulse) (Fig. 19-3). If corneal sensation is to be preserved the several deepest or most medially placed fibers are left intact. Gravitation of blood into the subarachnoid space through the opening in the sheath can be obviated by placing gelfoam over the opening. Usually hemostasis is simple with a little attention to bleeding points on the dura and the wound can be closed without drainage.

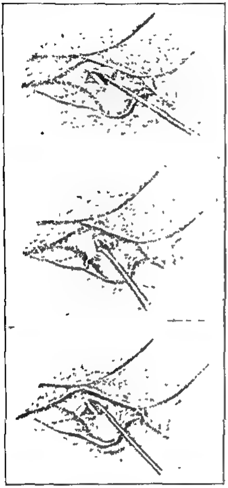

Fig. 19-3. Shows exposure of gasserian ganglion and section of sensory root Top, ganglion sheath has been opened to expose root. Center, root is divided and lower part cut to expose motor root. Bottom, sensory root has been four-fifths avulsed leaving motor root and fibers to first division in place. (Courtesy of Francis Grant.)

There are a number of variations of this method that the surgeon may choose deliberately or by expedience if difficulties arise at the time. For example, the dura may be opened (or torn) lateral to the foramen spinosum, the temporal lobe retracted and the sensory root of the nerve exposed by opening the overlying dura and sheath. In the extradural operation of partial rhizotomy some surgeons open the sheath over the ganglion and identify the point of emergence of the first and second divisions from the ganglion. From this point a split is made backward in the ganglion emerging into the root and then dividing all the fibers lateral to this point; the most medial fibers should be the ones supplying the first division of the nerve. Another variation which has been found useful when the pain is limited to the maxillary area is a V or wedge-shaped incision in the ganglion with the apex at the posterior margin of the ganglion and the sides of the V encompassing the second division as it emerges from the anterior margin of the ganglion. This operation has the advantage of pres[illegible] in

infrequent occurrence It is believed the inflammation results because of the complete insensitivity of the cornea, in consequence, the wink reflex is abolished and patients are unaware of the presence of irritating foreign matter that abrades the cornea About 20 per cent of patients with anesthetic cornea after rhizotomy develop some degree of keratitis, but fortunately if care is taken to protect the eye by irrigation or by temporary tarsorrhaphy if necessary, recovery takes place Very occasionally through carelessness of the patient or physician serious corneal ulceration and iritis will require enucleation of the eye The danger of serious keratitis seems to be less after the patient has passed through the immediate postoperative period and learned the need for protecting the eye It is always advisable for patients with corneal anesthesia to wear glasses, sometimes with marginal shields when the eye is exposed to wind and dust.

Herpes simplex is a common, though relatively unimportant, complication in the early postoperative period It occurs characteristically about the mouth but may occasionally involve also the inside of the mouth, tongue and palate on the side of the rhizotomy This interesting phenomenon may occur regardless of the site of section of the root and may even be seen following division of the descending tract of the trigeminal nerve in the medulla. It has long been realized that herpes simplex does not develop in areas of the face previously made anesthetic by alcohol injection of branches of the trigeminal nerve. The eruption, therefore, can deliberately be obviated if at the time of rhizotomy through a temporal approach a few drops of absolute alcohol are injected into the second and third divisions of the nerve.

A sense of fullness or deafness in the ear on the side of trigeminal rhizotomy is a fairly common postoperative complaint, but fortunately usually a transient one. The complaint is believed to result from several causes such as partial anesthesia of the ear drum, closure of the eustachian tube from postoperative soft tissue swelling and occasionally from blood in the inner and middle ear.

Paresthesias characterized variously as crawling, drawing, itching, and burning in the anesthetic areas are a common complaint occurring in more than half of the patients having sensory rhizotomy. Most patients accommodate for these sensations and are willing to accept them in exchange for their tic douloureux but a few, particularly those of advanced age, become increasingly miserable and develop obsessive compulsive reactions. Treatment is very unsatisfactory and even frontal lobotomy sometimes employed has provided little, if any, help

Recurrent tic douloureux can be expected in 10 to 15 per cent of those having partial rhizotomy and in these it may be necessary to perform total rhizotomy Bilateral tic douloureux is rare and patients can usually be reassured on this point Among the majority of those who develop bilateral tic douloureux there is a high incidence of disease of the central nervous system such as multiple sclerosis and syphilis

Tractotomy: Section of the Descending Tract of the Trigeminal Nerve. In the hope of avoiding total anesthesia and possibly dysesthesias which occur with division of the sensory root of the trigeminal nerve, Sjoqvist(13) in 1937 devised the operation of tractotomy whereby section is performed

The dura is opened and fluid is evacuated from the cisterna magna in order to facilitate retraction of the cerebellum and expose the cerebellopontile angle. Additional fluid is removed from the lateral cistern when the arachnoid is opened between the acoustic nerve and the petrosal vein which lies just behind the margin of the tentorium. The sensory root of the trigeminal nerve lies deeply in the space between the acoustic nerve and petrosal vein. It is usually safest to coagulate and divide the vein to avoid tearing it and it is important to protect the acoustic nerve or more especially the closely approximated facial nerve against the pressure of instruments while exposing and cutting the trigeminal nerve. If partial section of the root and preservation of sensation in the ophthalmic area is desired only the lower two thirds of the fibers in the root are divided. It is safest to divide the nerve close to the pons since damage to blood vessels is more likely to occur if the root is picked up more distally. The motor root of the trigeminal is rostral and may even be slightly separated from the uppermost fibers of the sensory root. The dura should be carefully sutured in closing the wound and no drains should be employed.

Results of Rhizotomy(7). In comparing the temporal and posterior approaches to trigeminal rhizotomy it was once believed for some strange reason that partial division of the sensory root near the pons did not result in significant, if any, sensory loss in the face. However, this is not the case and the same degree of sensory loss results regardless of whether the fibers of the sensory root are divided near the gasserian ganglion or the pons.

The advantages of the temporal approach are that the operative mortality is low (1 per cent, plus or minus) in the hands of almost all surgeons, whereas the mortality following the posterior intradural approach must be reckoned at a higher rate, particularly when it is performed by those less experienced in operating in this confined region. The motor root of the trigeminal nerve cannot always be preserved with certainty via the temporal route, whereas the motor root can easily be isolated and saved through the posterior exposure. This may be of great importance when it is necessary to perform a sensory rhizotomy for tic douloureux that develops in the other side of the face of a patient who has already had a rhizotomy with loss of the motor root on one side. Facial palsy, usually of temporary duration, can occur with either type of operation. In the temporal operation facial palsy is believed to result from traction on the petrosal nerves, the effect being transmitted to the geniculate ganglion. The traction of the nerves results when the dura with the adherent petrosal nerves is lifted from the petrous ridge in too vigorous retraction posterior to the gasserian ganglion. With the posterior approach the facial nerve is sometimes damaged by manipulation which may be an unavoidable complication during control of accidental bleeding from the petrosal vein or one of the vessels adjoining the trigeminal nerve.

Other complications or unfavorable sequelae of trigeminal sensory rhizotomy must be given consideration when offering the operation to a patient with tic douloureux. If the cornea is made anesthetic by the operation as may be necessary for relief of pain or may occur in spite of intention to preserve it there may be keratitis. Inflammation and ulceration of the cornea can be the result of herpes of the cornea, but if so it must be an

infrequent occurrence. It is believed the inflammation results because of the complete insensitivity of the cornea, in consequence, the wink reflex is abolished and patients are unaware of the presence of irritating foreign matter that abrades the cornea. About 20 per cent of patients with anesthetic cornea after rhizotomy develop some degree of keratitis, but fortunately if care is taken to protect the eye by irrigation or by temporary tarsorrhaphy if necessary, recovery takes place. Very occasionally through carelessness of the patient or physician serious corneal ulceration and iritis will require enucleation of the eye. The danger of serious keratitis seems to be less after the patient has passed through the immediate postoperative period and learned the need for protecting the eye. It is always advisable for patients with corneal anesthesia to wear glasses, sometimes with marginal shields when the eye is exposed to wind and dust.

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Recurrent tic douloureux can be expected in 10 to 15 per cent of those having partial rhizotomy and in these it may be necessary to perform total rhizotomy. Bilateral tic douloureux is rare and patients can usually be reassured on this point. Among the majority of those who develop bilateral tic douloureux there is a high incidence of disease of the central nervous system such as multiple sclerosis and syphilis.

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The dura is opened and fluid is evacuated from the cisterna magna in order to facilitate retraction of the cerebellum and expose the cerebellopontile angle. Additional fluid is removed from the lateral cistern when the arachnoid is opened between the acoustic nerve and the petrosal vein which lies just behind the margin of the tentorium. The sensory root of the trigeminal nerve lies deeply in the space between the acoustic nerve and petrosal vein. It is usually safest to coagulate and divide the vein to avoid tearing it and it is important to protect the acoustic nerve or more especially the closely approximated facial nerve against the pressure of instruments while exposing and cutting the trigeminal nerve. If partial section of the root and preservation of sensation in the ophthalmic area is desired only the lower two thirds of the fibers in the root are divided. It is safest to divide the nerve close to the pons since damage to blood vessels is more likely to occur if the root is picked up more distally. The motor root of the trigeminal is rostral and may even be slightly separated from the uppermost fibers of the sensory root. The dura should be carefully sutured in closing the wound and no drains should be employed.

Results of Rhizotomy(7). In comparing the temporal and posterior approaches to trigeminal rhizotomy it was once believed for some strange reason that partial division of the sensory root near the pons did not result in significant, if any, sensory loss in the face. However, this is not the case and the same degree of sensory loss results regardless of whether the fibers of the sensory root are divided near the gasserian ganglion or the pons.

The advantages of the temporal approach are that the operative mortality is low (1 per cent, plus or minus) in the hands of almost all surgeons, whereas the mortality following the posterior intradural approach must be reckoned at a higher rate, particularly when it is performed by those less experienced in operating in this confined region. The motor root of the trigeminal nerve cannot always be preserved with certainty via the temporal route, whereas the motor root can easily be isolated and saved through the posterior exposure. This may be of great importance when it is necessary to perform a sensory rhizotomy for tic douloureux that develops in the other side of the face of a patient who has already had a rhizotomy with loss of the motor root on one side. Facial palsy, usually of temporary duration, can occur with either type of operation. In the temporal operation facial palsy is believed to result from traction on the petrosal nerves, the effect being transmitted to the geniculate ganglion. The traction of the nerves results when the dura with the adherent petrosal nerves is lifted from the petrous ridge in too vigorous retraction posterior to the gasserian ganglion. With the posterior approach the facial nerve is sometimes damaged by manipulation which may be an unavoidable complication during control of accidental bleeding from the petrosal vein or one of the vessels adjoining the trigeminal nerve.

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of the descending tract of the trigeminal nerve which subserves pain sensation in the face *disassociated from touch sensation*. Originally the incision in the tract was performed at a level corresponding to the border between the middle and inferior third of the olivary eminence but there resulted injury to the restiform body and rootlets of the vagus nerve. Later the operation was revised by placing the incision more caudad, at or just below the level of the obex.

In performing the operation a midline occipital and suboccipital incision is employed, and the posterior margin of the foramen magnum and the arch of the atlas are removed. Through the opened dura the brain stem is exposed in its posterolateral aspect from the obex to the upper cervical levels. The longitudinal level of the incision is chosen in as avascular an area as possible in the three or four millimeters just caudad to the obex. The incision is started just lateral to the funiculus cuneatus and extended ventrally to a point just dorsal to the level of the vagus rootlets. The depth of the incision is about 3 mm.; a deeper incision may damage the nucleus ambiguus and sympathetic fibers. If the incision is carried too far in the dorsal direction, the posterior columns and their nuclei will be damaged, whereas extension of the incision too far ventrally will result in damage to the spinothalamic and spinocerebellar tracts. Sjoqvist advises that the operation be performed with the patient under local anesthesia in order to use the patient's assistance in regulating the extent of the incision. However, there are obvious limits to this method of determining the adequacy of the incision.

An operation of this kind can be expected to be accompanied by greater risk to life and by the possibility of more complications than rhizotomy. Were the results sufficiently good in terms of relief of pain, preservation of some sensation and avoidance of dysesthesias in the face, the risks of the operation might be acceptable at least in selected cases(9). However, the rate of recurrence of pain is about 35 per cent, keratitis occurs in some even though the degree of corneal reflex (through tactile sense) may be preserved and dysesthesias occur though they seem to be of a milder form than some that follow rhizotomy. It is most difficult to attain satisfactory analgesia in the mandibular area with tractotomy and since better than 65 per cent of patients have their pain in the mandibular area the operation is not well suited for this reason

Therefore, because trigeminal tractotomy is more dangerous than rhizotomy and because it is followed by a relatively great number of recurrences of pain it is not suitable as a routine procedure.

Decompression of the Trigeminal Root and Ganglia. In 1952 Taarnhoj (14) proposed decompression of the trigeminal nerve for treatment of tic douloureux by dividing the dura enclosing the root and ganglion without dividing the root itself. It was believed that, since neoplasms lying in the cerebellopontile angle adjacent to the trigeminal nerve occasionally cause tic douloureux which is relieved when the tumor is removed, then idiopathic tic douloureux might also be due to compression of the root. It was proposed that the point where compression of the nerve might be most likely to occur was where the root passed beneath the dura along the ridge of the

petrous bone (Fig. 19-1). An increased vulnerability of the root at this point with increasing age also seemed possible.

The operation as performed by Taarnhoj employs an incision and craniotomy like that for the temporal approach to trigeminal rhizotomy. The dura is opened and the temporal lobe elevated from the dura covering the floor of the temporal fossa. By inspection and palpation that part of the dura overlying the gasserian ganglion is identified and opened. The incision in the dura as well as in the root sheath is extended backward from the ganglion through the petrosal sinus and sometimes farther posterior through the edge of the tentorium, thus laying bare the entire course of the trigeminal root from the ganglion to the pons. Bleeding from the divided petrosal sinus may require measures for its control and a special hazard exists in the possible damage to the trochlear nerve which lies just beneath the tentorium near the line of its incision.

The author has employed general anesthesia and the supine position for the patient; also spinal drainage of cerebrospinal fluid to facilitate retraction of the temporal lobe. The operation thus performed is potentially hazardous though no significant complications have occurred in a dozen cases with the exception of transient trochlear palsy in several patients. The majority of the patients demonstrated mild sensory impairment in the area of the face supplied by the trigeminal nerve presumably as a result of trauma to the root while incising the dura or when employing tamponade to control bleeding from the petrosal sinus. As a rule, sensation returned fairly quickly. In this small series pain has not recurred within a period up to a year and a half after operation. In larger series reported by Taarnhoj and by the Mayo clinic, however, the recurrence of pain has been found to be at least 25 per cent in the first two years after operation

The technic of the operation has been modified by Love, possibly to advantage. The extradural temporal approach is employed as in the procedure of trigeminal rhizotomy, with the patient in the sitting position. The dura is reflected and retracted from the gasserian ganglion and root of the nerve, but in this case the dura is reflected farther backward until the petrosal sinus is exposed. In the process it may be necessary to use some sharp dissection to free the dura from the petrous bone and it is important to avoid traction on the petrosal nerves since traction may result in facial paralysis. The sheath of the root is not necessarily opened but an incision is made in the dura along a line above the root and the incision extended backward until the petrosal sinus is divided. This variation of the operation appears to have a distinct advantage in safety to the patient because it is chiefly extradural.

It is not at all certain why the operation of decompression of the trigeminal root should be effective. The presumed analogy of pain which occurs with pressure on the root from a tumor is not necessarily pertinent since in idiopathic tic douloureux the dura cannot be shown definitely to compress the root. The vagaries of tic douloureux and the various operations performed to cure it are numerous and it has been the experience of many surgeons that occasionally when little or nothing is done except to expose the root and traumatize it unaccountable relief of pain ensues However, if

lasting relief of tic douloureux without numbness should prove in time to occur in even half the cases treated by decompression of the trigeminal root the operation will be a great boon to the surgical treatment of this disease.

OTHER CRANIAL NERVES

The essentials of the technic for exposure of the fifth cranial nerve through the posterior fossa are similar to those for the exposure of the intracranial portion of other cranial nerves lying below the trigeminal. The other nerves which may be advantageously divided for therapeutic effect are the seventh (nervus intermedius), eighth, ninth, tenth (sensory portion), and the eleventh (Fig. 19-1). Appropriate variations of the suboccipital operation may be necessary for the exposure and section of the different nerves, but the descriptions in each case will follow a brief outline of the clinical indications for which operation on these nerves is performed.

The Facial Nerve (Nervus Intermedius of Wrisberg). The sensory division of the facial nerve is the nervus intermedius of Wrisberg. The condition known as geniculate neuralgia or geniculate tic douloureux is believed to be a disease of this nerve and is the rarest of the painful afflictions associated with the cranial nerves. Much of the knowledge of the sensory components of the facial nerve has come through the study of the location of pain and herpetic eruption in herpes zoster of the geniculate ganglion. Paroxysmal bursts of pain occurring principally deep in the ear though sometimes spreading to less well defined adjacent areas of the ear, face and head constitute a syndrome comparable to tic douloureux which more commonly involves the trigeminal and glossopharyngeal nerves. The author has seen but one case that would be acceptable as an example of this disease and only three cases have been reported in which surgical section of the nervus intermedius has been employed (Taylor(2), Furlow(5), and Wilson(15)).

In order to divide the nervus intermedius the surgical exposure should give an unhampered view of the cerebellopontile angle (Fig. 19-4). Drainage of cerebrospinal fluid from the cisterna magna and lateral cistern will facilitate retraction of the cerebellum providing ample exposure of the acoustic nerve which usually completely hides the facial nerve. If the surgeon directs his view downward along the plane of the tentorium into the angle it occasionally is possible to see the facial nerve exposed but still partly covered by the rostral margin of the acoustic nerve. By progressive retraction on the eighth nerve posteriorly the facial nerve can usually be adequately visualized. The sensory portion of the facial nerve, appropriately named the intermediate nerve, lies between the acoustic nerve and the motor component of the facial nerve. It is closely approximated to the motor division, but with care it can be separated and divided. There is a distinct risk of traumatizing the motor root causing facial palsy, but recovery should occur if the motor root is not divided. The author has had occasion to perform this operation as a part of multiple rhizotomy for intractable pain caused by carcinoma of the head and neck.

The Acoustic Nerve. The eighth cranial nerve is made up of two divisions: one is the vestibular portion made up of neurons which transmit impulses from the peripheral vestibular apparatus having to do with

balance; the other is the cochlear portion whose neurons come from the organ of Corti having to do with hearing. Ménière's disease, believed to be an idiopathic disease of some part of the eighth nerve, is characterized by paroxysmal attacks of vertigo and unilateral tinnitus referred to one ear in which hearing is impaired. The attacks of vertigo are frequently accompanied by vomiting and may be so severe that the patient is thrown off balance and may be prostrated for the duration of the vertigo which persists for a few minutes or many hours. Between attacks the patient may be quite well but for persistent deafness and more or less constant tinnitus in one ear. In the development of the Ménière's syndrome the three symptoms do not always make their appearance together and one or two of the symptoms may exist for many months before the third one appears to complete the full triad necessary for the diagnosis. When paroxysmal vertigo exists alone there is no way of knowing from which side it arises until tinnitus and hearing loss occur.

Spontaneous cure of the vertigo follows when total deafness ensues, indicating complete degeneration of the nerve. The same effect is assured by surgical division of the nerve(3) or by destruction of the end organs. The results of eighth nerve section are very good in terms of relief of vertigo but tinnitus is not always relieved and hearing is usually made worse unless a differential section of the nerve is performed by which the cochlear neurons are preserved. In case it is important to attempt to preserve hearing, partial section of the nerve is justified if it is recognized that in doing so some of the vestibular fibers may be unwittingly spared and the result of the operation thereby compromised.

The same type of surgical approach employed in exposing the trigeminal nerve by the posterior route provides the exposure needed for section of the eighth nerve (Fig. 19-4). The arachnoid should be brushed aside to lay the nerve bare and it is safer to identify and avoid the auditory artery before attempting to divide the nerve. The artery may lie in almost any position with relation to the nerve and occasionally cannot be seen until at least a part of the fibers are divided. The danger of bleeding from the artery lies in the possible injury to the facial nerve that may accompany measures employed for hemostasis. If the facial nerve can be identified beneath the upper margin of the eighth nerve the rest of the operation is simplified, but if the facial nerve cannot be seen then the fibers of the eighth nerve must be picked up with a nerve hook and divided a few at a time. If a partial section is desired whereby only the vestibular fibers are divided, leaving at least some of the auditory fibers for preservation of hearing, then the anterior two thirds of the nerve is cut. Often a thin line of demarcation between the two divisions of the nerve may be seen and this serves as a guide in separating the two. The actual division of the nerve may be done with a sharp cutting tool or the fibers may be safely interrupted by touching the nerve hook, which holds them up, with the cutting current of the endothermy. In the author's experience with nearly a hundred cases death ensued in one case from an unrecognized hemorrhage in the cerebellum. Transient and insignificant facial palsy occurred in but a few cases and the only failures in the relief of vertigo were in three cases in which some of the vestibular fibers were inadvertently left in performing partial section of the nerve.

The Glossopharyngeal and Sensory Fibers of the Vagus Nerves. The principal interest in the ninth nerve is in relation to glossopharyngeal tic douloureux which though not as common as trigeminal tic douloureux is still not a rare disease. It is characterized by paroxysms of sharp, brief pain in the tonsilar region and is usually induced by swallowing or by internal or external pressure in the tonsillar region. Section of the ninth nerve intracranially is an eminently satisfactory operation since it relieves the pain without producing any sequelae from nerve deficit of which the patient is aware(1).

The ninth nerve also serves as a pathway for the afferent impulses of the carotid sinus reflex that are dependent upon pressure effects on the carotid artery. A hypersensitive carotid sinus reflex may induce attacks of asystole and syncope which can be terminated, particularly in older patients with sclerosis of the carotid, by section of the ninth nerve intracranially. Rarely patients with glossopharyngeal tic douloureux develop asystole or bradycardia and syncope concomitant with the paroxysms of pain.

Another condition in which intracranial section of the ninth nerve can be useful is in abolishing the disagreeable sweating on the side of the face in the auriculotemporal syndrome. This syndrome, characterized by excessive sweating in the pre-auricular region of the face at the time of eating, results from abnormal union of the chorda tympani and the auriculotemporal branch of the trigeminal nerve following penetrating wounds or surgical procedures in the parotid region. Division of the ninth nerve permanently interrupts the reflex and leaves no untoward effects.

The surgical approach to section of the glossopharyngeal begins precisely as for the exposure of the fifth, seventh and eighth nerves in the posterior fossa (Fig. 19-4), but for the ninth nerve it is not necessary to be so exacting in making available every bit of space in the upper and lateral reaches of the exposure. After evacuation of fluid from the lateral cistern the arachnoid is gently brushed aside to expose the nerves entering the jugular foramen. The fibers of the ninth, tenth and eleventh nerves enter this foramen and there should be no difficulty in identifying the glossopharyngeal which is uppermost (cephalad) and represented by a single nerve, usually set slightly apart from the smaller and numerous fibers of the vagus. Usually section of the ninth nerve alone is adequate but experience has shown that occasionally glossopharyngeal tic douloureux is relieved only by the additional severence of the upper two filaments of the vagus. Therefore, it is safer to divide these fibers of the vagus whenever it is necessary to section the glossopharyngeal nerve for relief of pain. No untoward effects have followed vagus nerve section of this extent. In the majority of patients there occurs a rise in blood pressure of variable degree when the ninth nerve is sectioned due to interruption of the regulatory mechanism of the carotid sinus reflex on that side. But the rise is always compensated for by other mechanisms and it is rare for the pressure to remain significantly elevated after several hours.

The Spinal Accessory Nerve. Surgical division of the spinal accessory nerve has been of importance only as part of multiple nerve section employed in the treatment of spasmodic torticollis(12). This condition, also known as wry neck, is characterized by irregular and clonic spasms of the

neck muscles which turn the head forcibly. The etiology of the condition is unknown and there may be more than one etiologic factor. The majority opinion is that the movements are wholly related to mental conflict and do not result from pathologic changes in the central nervous system. Others believe that pathology at some point in the extrapyramidal system gives rise to torticollis and cite examples of the condition following encephalitis or as a part of more generalized dystonia musculorum deformans.

Because the tense and hypertrophied sternomastoid muscles are usually most easily seen and examined they may erroneously be looked on as the offenders. The trapezii also sooner or later take on a quality similar to the sternomastoids. Surgical treatment has commonly been directed toward dividing these muscles or to denervating them by division of the spinal accessory nerve extracranially. Except as an adjunct to psychotherapy in an occasional patient these procedures are useless. All muscles of the neck take part in the movements of torticollis and to abolish the movements with any degree of certainty it is necessary to paralyze all or nearly all of the neck muscles. This can be accomplished only by dividing the spinal accessory nerves intracranially together with the first four cervical motor roots on both sides. The operation is sometimes performed in stages in an effort to determine whether something less than extensive rhizotomy will be useful; but results are nearly always disappointing, since the existence of any musculature adequate to support the head and turn the neck may be sufficient to perpetuate the torticollis. If all the muscles are paralyzed new problems may be introduced in that a supporting collar must be worn constantly and serious difficulty with swallowing may develop. Therefore, surgical treatment should be reserved for the most severe cases of torticollis and utilized only after weighing all factors.

The surgical procedure for bilateral rhizotomy of the spinal accessory and upper cervical motor roots requires a midline incision from the occipital protuberance to the midcervical region. General anesthesia and probably curare are necessary to obtain sufficient quiet and muscle relaxation. The occipital bone is partly removed, the foramen magnum opened widely and the upper three cervical lamina removed. After the dura is opened the spinal accessory nerve can be exposed on each side by retracting the cerebellum. The nerve lies at the posterior margin of the jugular foramen and stands out as a heavier trunk than the finer rootlets of the vagus nerve just rostral to it. If the combined nerve is not cut at the foramen attention must be given to assure division of both the spinal and the accessory portions. The anterior cervical roots from one to four are readily isolated by identifying their position anterior to the dentate ligaments and each divided near the point of emergence through the dura. Small blood vessels travelling with the nerve roots may require ligature or clipping if they cannot be separated. The dura is reapproximated and the wound closed in layers.

Cranial Nerve Section for Relief of Painful Malignant Lesions of the Head and Neck. A great variety of malignant tumors invading the head and neck region result in pain of such degree that pain-relieving drugs soon become ineffective and the patient's already unhappy plight is made increasingly difficult. Though there are obvious limits to what can be expected

from nerve sections, there are many instances in which rhizotomy of appropriate cranial and cervical nerves may be a godsend to the patient thus afflicted(8).

Painful lesions of the upper part of the head and face such as the orbit, nose, maxilla and paranasal sinuses will be benefited by trigeminal rhizotomy. Lesions of the mandible, tongue, and floor of the mouth occupy areas supplied by the trigeminal, upper cervical, and possibly the glossopharyngeal nerves. Lesions in the pharynx and larynx particularly require section of the ninth and sensory portion of the tenth cranial nerves and of the upper four cervical sensory roots for relief of pain. If any of the lesions and particularly those in the pharynx are accompanied by pain deep in the ear it may be desirable to divide, among other nerves, the sensory portion of the facial nerve (nervus intermedius). Occasionally section of the facial nerve is simplified by the fact that a facial palsy already exists, thus obviating the need for a tedious differential section of the nerve.

For lesions in the upper part of the face in which the only sensory supply is the trigeminal nerve the rhizotomy may be carried out via the temporal approach (Fig 19-3). But for most other lesions about the head and neck multiple sensory rhizotomy can best be accomplished through the posterior approach (Fig. 19-4). If the operative exposure designed for the posterior approach to the trigeminal nerve is employed all of the other sensory cranial nerves are equally well exposed and it requires but a few minutes to section the remaining nerves after the trigeminal has been dealt with. It is even appropriate to combine the operation with a hemilaminectomy by extending the medial leg of the U-shaped incision down the midline of the neck to expose the laminae. A hemilaminectomy of the first three cervical vertebrae provides ample exposure of the cervical sensory roots on the side which requires section. Usually it is best to divide all of the first four sensory roots, remembering that the fourth root lies above the level of the fourth cervical lamina and that the first cervical sensory root, present in but one tenth of patients, may be a small and easily overlooked root but none the less important. In the presence of painful lesions which lie wholly below the trigeminal area multiple rhizotomy need not include the trigeminal and the whole procedure is facilitated.

The descending tract of the trigeminal nerve is believed to include also pain fibers of the glossopharyngeal vagus and possibly the facial. Therefore, a successfully performed tractotomy in the brain stem just below the level of the obex should accomplish all that could be expected from the more tedious operation of multiple cranial rhizotomy. In a few cases the author has found tractotomy very satisfactory for relief of pain and, too, this operation can rather easily be combined with upper cervical laminectomy and cervical rhizotomy, both being performed through one ample midline incision. The principal disadvantage of the tractotomy is that if loss of sensation in the trigeminal area is incomplete the area spared is likely to be in the mandibular region where the anesthesia is usually most desired.

Greater Superficial Petrosal Neurectomy. Surgical relief of various forms of headache and atypical facial pain have been sought for years with what can only be regarded as dismal failure. There are numerous reasons for

the failure, but the chief one is that the pains for which relief is sought usually arise from blood vessels and skeletal muscles and have a multiple and often incompletely understood nerve supply. The most recently developed attempt to relieve orbital facial pain and other vascular pain of the head and face is by section of the greater superficial petrosal nerve(6). Though the results thus far are not wholly encouraging, more experience is necessary before making final conclusions. The greater superficial petrosal nerve is believed to include afferent fibers from the dura mater, the internal carotid artery and the sphenopalatine ganglion and secretory fibers to the lacrimal gland and nasal mucosa, with vasodilator fibers distributed to the nasal mucosa (possibly also vasodilator fibers to the cerebral vessels).

Interruption of the lacrimal fibers in the nerve results in a partial loss of tearing and thus has been put to therapeutic use in the treatment of the syndrome of crocodile tears and of bullous keratitis.

The surgical approach to the greater superficial petrosal nerve is the same as that utilized for the temporal exposure of the trigeminal root (Fig. 19-2). The middle meningeal artery may be divided at the foramen spinosum before the dura is retracted from the petrous bone or the artery may sometimes be left intact since the petrosal nerves (greater and lesser) lie just behind and deep to the foramen spinosum (Fig. 19-1). The greater superficial petrosal nerve will be found lying in a small groove in the petrous bone. It enters the skull through the hiatus fallopii posteriorly and if traced anteriorly is seen to pass beneath the anterior margin of the gasserian ganglion. The nerve is easily divided once identified but it is very important to avoid traction on it at any time since the effect may be transmitted to the geniculate ganglion and result in facial palsy.

The Extracranial Portion of the Facial Nerve. Disturbances of the motor division of the facial nerve are evidenced either by paralysis or by paroxysmal hemifacial spasm. Paralysis of the facial nerve may result from operations on the parotid, mastoid or in the cerebellopontile angle and from lacerations of the face, skull fracture, Bell's palsy, otitis media, petrositis, tumors of the petrous bone, intracranial tumors, facial nerve tumors, geniculate herpes zoster, birth injury, and congenital maldevelopment. Hemifacial spasm is most commonly the sequel of facial paralysis with incomplete recovery though the etiology is not always evident, and the condition must be differentiated from facial tic or habit spasm which is purely a neurotic manifestation(10).

In the treatment of facial paralysis the goal of any surgical procedure is the physiologic restoration of nerve function. In Bell's palsy, which is the commonest type of facial paralysis, the usual treatment is expectant since about 85 per cent of the patients recover spontaneously. There are some proponents of decompressing the facial nerve in the facial canal, particularly when response to faradic stimulation is absent or if spontaneous recovery is arrested before complete return of function. However, it would seem that for decompression to be effective it should be instituted before degeneration has taken place and a policy of this kind is hardly justified in view of the high incidence of spontaneous recovery.

Trauma to the facial nerve resulting from mishap in mastoid operations once a not uncommon occurrence is now almost a thing of the past since

the advent of antibacterial medications has nearly done away with the need for mastoid operations. However, injury to the nerve is greater today due both to auto accidents and to more radical operations both intracranial and extracranial. The goal of surgical procedures on the facial nerve is physiologic restoration of its function, and end-to-end suture whenever possible is desired above all other procedures. Nerve grafting in the canal for the facial nerve has sometimes been found to give fairly good results,

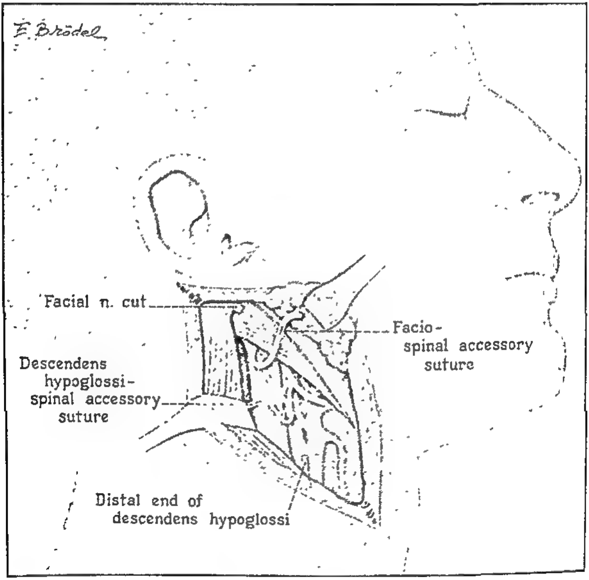

Fig. 19-5 Sketch showing anastomosis of the spinal accessory nerve to the facial nerve, and of the descendens hypoglossi to the distal end of the spinal accessory nerve.

but the most commonly employed method of restoring facial motility when ends of the divided nerve cannot be brought together is anastomosis of the distal stump of the nerve to the central end of an adjacent cranial nerve such as the spinal accessory or the hypoglossal(11).

If an anastomosis with an adjacent cranial nerve is to be employed the operation should not be delayed needlessly, and it is commonly performed in two to four weeks after removal of an acoustic neurinoma in which the facial nerve is sacrificed. On the other hand, good results may still be

obtained when an anastomosis is performed many months later. In one case of the author's experience nearly three years elapsed between paralysis and nerve anastomosis, and satisfactory facial motion was restored Of course, the result always leaves something to be desired when hypoglossofacial or spinofacial anastomosis is performed, but the result is far superior to the results from plastic procedures that must be resorted to when all forms of nerve repair are impossible There is relatively little to choose from in deciding whether to perform anastomosis with the hypoglossal or the spinal accessory. The author has tried both and favors the latter for most patients principally because in a few instances the hypoglossal anastomosis has been accompanied by undesirable adventitious movements of the face during talking and eating

In the performance of spinofacial or hypoglossofacial anastomosis either local or general anesthesia can be employed The incision is made along the anterior border of the sternomastoid muscle extending downward from the level of the mastoid process (Fig 19-5) The facial nerve is located at the point of emergence from its canal in the mastoid bone. Usually, if the nerve is divided at this point a centimeter or so of the trunk can be mobilized distally to facilitate the anastomosis or if not, the bony canal can be opened a short distance and the facial nerve cut inside the canal. If the anastomosis is to be with the spinal accessory nerve (Fig 19-5), it is identified as it passes under the digastric muscle and divided at its point of entrance into the sternomastoid muscle. The central end of the spinal accessory nerve is joined to the peripheral end of the facial nerve by a fine arterial silk suture passed through the center and about two millimeters from the end of each nerve trunk. The silk loop is pulled up enough to bring the nerve ends together but not cause buckling Sometimes it is profitable to divide the descending hypoglossal nerve two or three centimeters below its origin and anastomose its central end to the distal end of the divided spinal accessory. The muscle deficit produced by dividing the descending hypoglossal is unnoticed by the patient, and in about half the author's cases there has resulted a fair degree of innervation of the muscles supplied by the spinal accessory nerve. In women, particularly, the preservation of tone and of weak movement in the sternomastoid muscles preserves the symmetry of the neck.

If the facial nerve is to be anastomosed with the hypoglossal nerve the latter is found emerging from beneath the angle between the two bellies of the digastric muscle (Fig 19-6) A fairly long segment of the nerve is easily exposed here as it passes downward across the carotid arteries. There is ample amount of the nerve when divided to suture the proximal end into the distal end of the prepared facial nerve without tension. There is probably some advantage in minimizing atrophy of the homolateral side of the tongue if the descending branch of the hypoglossal nerve is divided and its proximal end sutured to the distal end of the divided hypoglossal.

In the surgical treatment of facial hemispasm the aim is to interrupt the peripheral portion of the facial nerve enough to reduce the innervation but not enough to paralyze the muscles completely. Temporary complete paralysis of the nerve is of little use because the spasms always recur in their original degree when the nerve function returns. No surgical treat-

ment yet devised has proved wholly satisfactory either because insufficient paralysis does not stop the spasms or more complete paralysis is undesirable or initial benefits are not lasting due to the propensity of the facial nerve for regeneration. Even so, beneficial results have occasionally followed selective interruption of peripheral branches of the nerve.

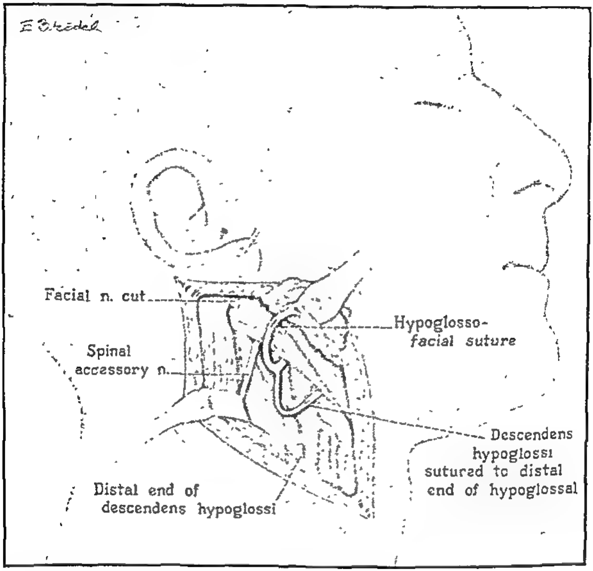

Fig. 19-6. Sketch showing anastomosis of the hypoglossal to the facial nerve, and of the descendens hypoglossi to the distal end of the hypoglossal nerve.

The surgical exposure of the branches of the facial nerve is a relatively simple matter though requiring patience. There is an advantage in using local anesthesia since the effect of sectioning successive branches of the nerve on both voluntary and involuntary facial movements can be determined. It is also important to employ an electric stimulator to identify the nerves and their area of innervation. The incision is made beginning just above the upper margin of zygoma in the pre-auricular region and continuing downward to the angle of the jaw, then forward along or just beneath the border of the mandible. The superficial fascia is incised and a flap of skin and fascia reflected anteriorly thus exposing the parotid gland. The various branches of the nerve emerge from beneath the anterior and

superior margin of the parotid. There are three main branches of the facial nerve, one of which supplies the forehead and periorbital region, another the maxillar and upper lip regions, and another the chin and mandible. But each of these three branches arborizes at or just beyond the margin of the parotid. Blepharospasm is often the most troublesome part of facial hemispasm and in some cases it may be desirable to lessen the action of the orbicularis muscle only. In that case as many branches of the nerve as possible are identified at and just above the zygoma. All but one to three of the small branches are usually divided but the decision can best be made in a step by step procedure employing observation of the effect on the spasm, response to electric stimulation, and voluntary motion. Sections should be resected from the nerves that are divided and if possible the remaining peripheral portion avulsed. A comparable procedure is used for the maxillary and mandibular branches if the spasm significantly involves the lower part of the face.

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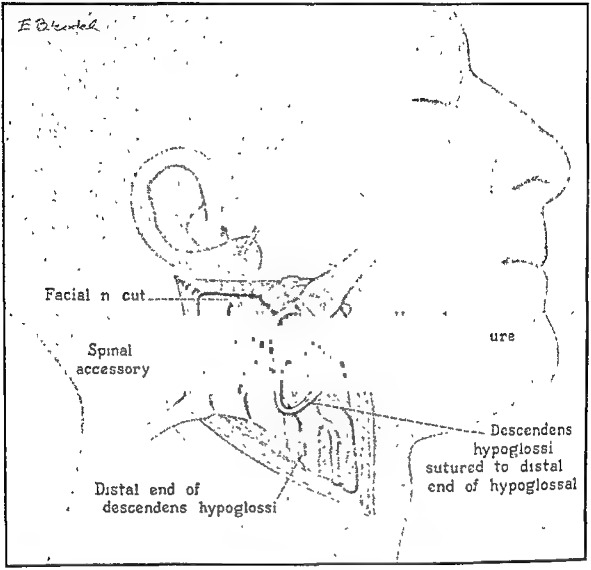

Fig 19-6 Sketch showing anastomosis of the hypoglossal to the facial nerve, and of the descendens hypoglossi to the distal end of the hypoglossal nerve

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requires removal the decision can then be made as to whether the uterus should be removed by the vagina or through the abdomen.

REPAIR OF THE CERVIX

Indication. Whenever laceration of the cervix has occurred which results in exposure of the cervical mucosa repair is indicated. This operation has been much neglected in recent years. Electrical conization as suggested by Hyams is far more popular. In many instances, however, a severe erosion or chronic infection of the cervix will be better treated by cervical repair than by cauterization whether by radial striations or by cone. A complete coverage by normal epithelium results. This is excellent prophylaxis against the subsequent development of cancer in the cervix.

Technic. As Graves has observed, many of these badly lacerated cervices will prove to be unilateral tears if the tenacula are placed exactly in the midline as indicated by the central raphe from which radiate the branching folds of the cervical mucosa. By bringing the two tenacula together the extent of the laceration is determined. This is important lest a deviated canal result which may subsequently produce stenosis. The cervix is dilated to permit ease of operation.

The two tenacula are then separated, exposing the area to be denuded. This is then outlined in normal cervical mucosa, taking care that a symmetrical denudation results, in order to avoid distortion. A heart-shaped type of denudation is commonly indicated with the pointed end of the heart extending as far up the cervical wall as is indicated by the depth of the laceration (Fig. 20-1). The common error is to make the width of the V-shaped arms too narrow rather than too wide. Stenosis of the canal may then result. The outline is continued on the mucosal side.

The actual denudation is then begun on the posterior lip in order to prevent the field from being obscured by bleeding from cut edges above. The depth of the denudation ranges from 2 to 4 mm. It is desirable to remove the tissue en bloc, consequently, after completing the dissection on the posterior lip, the anterior lip is sectioned in a similar manner and the entire area excised in one piece.

Where the laceration has been deep and the excision of necessity high, troublesome bleeding may be encountered from a cervical branch of the uterine artery usually encountered at the angle. This is best handled by a figure-of-eight stitch ligature.

Suturing of the laceration should be done with No. 0 catgut on a curved cutting needle. The first suture which may be used to control bleeding from the small branches of the cervical artery passes through the vaginal mucosa above the apex of the V-shaped denudation. Passing through the tough cervical tissue it emerges in the cervical canal. Continuing on its course the suture is passed from within outward, through the posterior cervical mucosa again about the angle (Fig. 20-2).

It may not always be easy to place this stitch. Graves suggests a simple means of avoiding embarrassment by threading a needle on each end of a suture and then successively passing the needles through the cervical tissue and mucosa. This difficulty usually arises on the first suture alone.

20

GYNECOLOGIC SURGERY

JOE VINCENT MEIGS AND LANGDON PARSONS

The operations described in this chapter are those found to be most useful in the ordinary gynecologic practice. Various minor procedures have either been omitted entirely or are mentioned only briefly. Operations performed infrequently have not been considered. The accepted indications for the procedures are included. The detailed anatomy of the structures involved are described in great detail in most textbooks of gynecology. The operative descriptions presented in this chapter stress the knowledge of correct anatomic relationships in order that the operative steps may proceed with the greatest ease for the surgeon and safety for the patient.

DILATATION AND CURETTAGE

The indications for dilatation and curettage either as the sole procedure or in combination with others are many and varied.

Dilatation. One of the earliest theories of dysmenorrhea implicated cervical obstruction. Dilatation is still an effective maneuver. Tearing of the parasympathetic nerve fibers in the plexus in and around the external os may bring relief. Stenosis of the cervical canal may result from senile atresia secondary to radium, atrophy, disease, or application of caustics to induce abortion. A pyometrium may result which requires evacuation through cervical dilatation.

Curettage. The dilatation is always followed by curettage of the endocervical canal and uterine cavity. If the symptoms suggest possible malignant disease within the uterus the two areas should be investigated independently and specimens separately labeled for laboratory interpretation. Every piece however small should be sent to the laboratory. Curettage is employed to empty the uterus of retained products of pregnancy; to remove the endometrial lining in cases of functional bleeding, both for cure and diagnosis, to explore the uterine cavity for the possible presence of malignant disease, polyps, or a submucous fibroid. Following the curettage the cavity should be explored with grasping forceps to be certain that polyps or malignant disease have not been overlooked. Special attention should be directed toward the cornua of the uterus

Dilatation and curettage together with pelvic examination should be performed in every instance as a preliminary step before every laparotomy performed for pelvic pathology Investigation of the uterine cavity and re-evaluation of the pelvis with regard to pathology hitherto unsuspected is a valuable maneuver in gynecologic surgery. It will also be useful in making a choice for any given vaginal procedure. If a tumor of the uterus

vents in a badly lacerated cervix the cervix may be brought within the scope of a normal repair by removing transverse wedge-shaped sections from both anterior and posterior lips and closing them with interrupted catgut sutures.

SURGICAL CONIZATION

Whenever the vaginal smear or punch biopsy has suggested the possibility of malignant change without sufficient evidence of degree of invasion, the removal of a complete circular segment of the squamocolumnar junction and endocervical tissue is indicated in order that proper therapy may be instituted. This applies particularly to carcinoma in situ. Adequate tissue is needed by the pathologist for proper evaluation. Electrical conization may destroy tissue and make the diagnosis difficult. The removal of the entire cone is a better method of providing the proper tissue for laboratory interpretation than punch biopsies taken from widely separated areas. After the cone of tissue has been removed surgically it is then permissible to cauterize or coagulate the raw areas that remain in order to control bleeding.

Cauterization of the Cervix. In the face of a shallow transverse laceration with exposure of the endocervix cauterization of the cervix is a satisfactory procedure. A series of deep linear striations is made in the cervix with a moderately hot cautery tip at spaced intervals from the external os out into normal tissue and upward to the level of the internal os. The adjacent tissues should be protected with moist gauze to prevent accidental burning.

Conization of the Cervix. Whenever the cervical infection appears to involve the deep cervical glands the use of electric cauterization applied through a wire of the Hyams type will remove a cone-shaped piece of tissue as the handle of the desiccator is slowly turned on its long axis. If the cone is too wide or carries too deeply into the cervical musculature the surgeon may be plagued with cervical stenosis as the repair process takes place. Troublesome bleeding in the immediate postoperative period and stenosis later on represent the disadvantages of this procedure. To overcome the latter, the patient should return for office dilatation to insure patency of the canal.

AMPUTATION OF THE CERVIX

Indication. When a chronically infected cervix is present which does not lend itself to electrical conization, amputation of the cervix may eliminate the entire gland-bearing area. Following this procedure pregnancy is harder to achieve and maintain. This represents a definite disadvantage to the procedure as a method of choice.

The chief indication for amputation arises in uterine prolapse of varying degrees of severity. It forms an essential part of the technic of the Donald-Fothergill operation in which the cervix becomes elongated as the bladder is advanced.

Technic. The cervix is grasped with a tenaculum on the anterior lip and the cervical canal slowly dilated. The uterine cavity is curetted to rule out tumors, cancers, or polyps. After the canal is dilated, tenacula are placed

The number of sutures necessary to complete the closure are placed. The sutures should be firmly tied, but they should be left loose enough to allow for swelling of the catgut (Fig. 20-3).

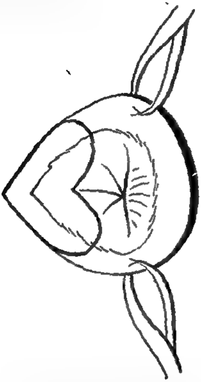

Fig 20-1. The two lips of the cervix are placed on traction by tenacula. The median raphe is evident and the heart-shaped area for denudation has been outlined.

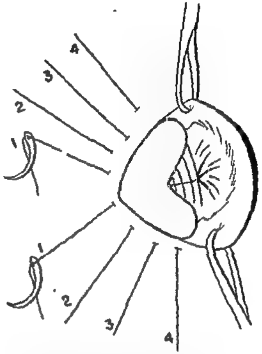

Fig. 20-2. The sutures have been placed, including the suture No 1, at the angle. They may be seen to pass through the substance of the cervix passing into and out of the cervical canal.

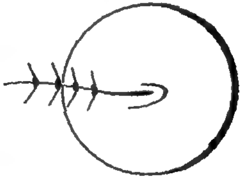

Fig. 20-3 The sutures have been ligated without tension to complete the closure of the defect.

Where the tear is bilateral the procedure is repeated with the assistant drawing the cervix in a contralateral direction.

It is not always possible to outline a symmetrical denudation. Where one lip is longer than the other the disproportion in length of one lip over the other may be corrected by placing more traction on one lip than the other, thus creating a new lateral angle.

This maneuver, while effective, has its limitations and it may be necessary to perform a transverse wedge-shaped amputation of the overlong anterior lip. Where an extreme redundancy of endocervical mucosa pre-

The direction of traction on the tenacula is changed to the axis of the vagina and a circular incision is made in the anterior cervical wall approximately one-half inch proximal to the external os. The cutting edge is beveled slightly so that the incision passes obliquely into the cervix, thus permitting a moderate cone of cervix to be removed. This cone should not be exaggerated. The endocervical canal should not be entered at this stage (Fig. 20-5).

The cervix is lifted upward again and the same maneuver is carried out posteriorly, connecting the two incisions laterally. A moderate cone is developed to the level of the internal os.

To maintain traction the tenacula are now shifted to the apex of the cone at each lateral angle, and the amputation is completed.

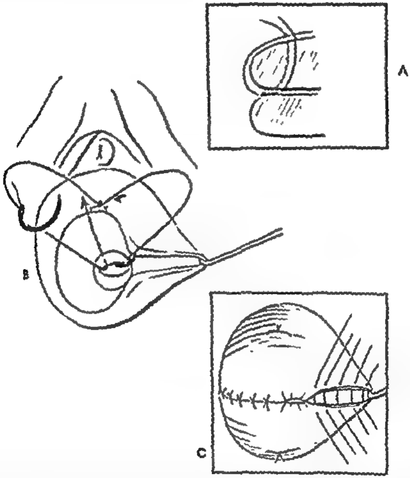

Fig. 20-6. A, placing of the modified Sturmdorf stitch. The initial suture has been tied at the *mucosal* edge. The first needle passes from the cervical canal to the cervix to emerge at the path the second suture is to follow. B, a lateral view to show how the vaginal mucosa is drawn over the cut edge of the cervix and into the canal as the suture is tied. C, indicating the completed ligatures of the anterior and posterior Sturmdorf sutures as well as the lateral sutures on the right.

A most important stitch (modified Sturmdorf) is then placed both anteriorly and posteriorly, designed to pull the mobilized mucosa up into the new *external os*, thus covering the raw edges (Fig. 20-6). Anteriorly the stitch passes through the midportion of the sectioned vaginal mucosa approximately 2 mm. from the edge. The suture of No. 0 catgut is tied once, leaving two long ends. The end with curved cutting needle attached is passed from within the cervical canal, through the substance of the

through the anterior and posterior lips and traction applied. The lower limits of the bladder on the cervix may be determined by introducing a probe through the urethra. Damage to the bladder may be avoided in this manner, for a circular incision is now made through the transverse folds of the vaginal mucosa while maintaining traction on the cervix with the tenacula as the assistant keeps the anterior wall on tension with gauze (Fig. 20-4).

By holding the vaginal mucosa and lifting up toward the urethra the vaginal mucosa is stripped back from the wall of the cervix to the level of the internal os. By following the maxim of staying on the uterine side there is little chance of injury. The natural planes of cleavage allow the maneuver to be accomplished with a minimum loss of blood.

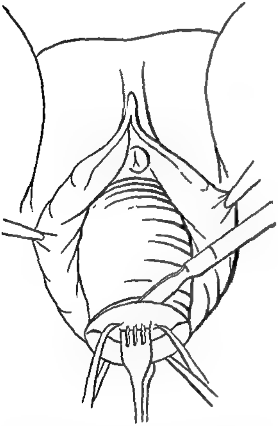

Fig. 20-4. Note the application of the double hook and the two tenacula to provide traction. The circular incision has been started immediately distal to the last transverse fold in the anterior vaginal mucosa

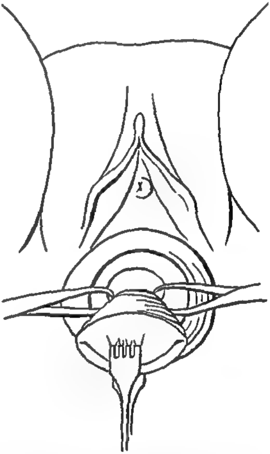

Fig. 20-5. A shallow cone has been developed with its apex in the cervical canal as the amputation progresses. The tenacula have been placed that traction may be maintained after the cervix is amputated

The cervix is pulled upward toward the urethra by traction on the tenacula, thus exposing the posterior cervical wall. The circular incision is then carried posteriorly and connected with the incision previously made in the anterior vaginal wall. The cut edge of the vaginal mucosa is picked up with forceps and the mucosa dissected from the posterior wall of the cervix by scissor or gauze dissection Inasmuch as the posterior cul-de-sac lies on a somewhat deeper plane and above the level of the *internal os* there is little danger of entering the abdomen.

and drainage is the primary consideration and is a definite indication for its ultimate removal.

Operation. An incision is made through the skin over the cyst and the cyst wall is exposed. With sharp knife dissection the cyst is completely excised from its bed. A considerable amount of bleeding may be encountered from vessels, especially in the upper end of the wound. The cyst should be removed in toto. Then the dead space is obliterated by catgut sutures and a small wick placed into the cavity just before the skin is closed. The closure of the skin can be done by means of catgut or silk sutures.

An acute abscess of Bartholin's gland is best treated by incision and evacuation of the pus. The cavity is then packed with thin strips of iodoform gauze. At the end of four days the abscess and the inflammation have subsided; the gauze is then withdrawn and under anesthesia, with the index finger in the cavity, the dissection of the cyst wall is carried out as described.

SIMPLE PERINEORRHAPHY AND REPAIR OF RECTOCELE

Indications. Indications for repair of the perineum are numerous. Most important is the anatomic reconstruction necessary following total abdominal hysterectomy or vaginal hysterectomy where the pelvic floor is reconstructed. The well-repaired and solid perineum takes the strain off the new peritoneal floor as pressure pushes the peritoneum downward.

Rarely is the operation carried out as the only vaginal procedure, for defects in the posterior vaginal wall of themselves give rise to symptoms infrequently. It is used in conjunction with other procedures such as cystocele repair, or Donald-Fothergill operation where reapproximation of the levators and reduction of the rectocele provides additional pelvic support.

The difference between simple perineorrhaphy and rectocele is largely a question of extent of separation of normal tissues. In simple perineorrhaphy the levator muscles separate at the perineal body. Where rectocele is present the separation is more pronounced as the rectum bulges out into the vagina through the defect.

Operation. Allis clamps are applied at the point of exit of Bartholin ducts and traction is applied laterally by the assistants. The tissue between the clamps is excised including the scar and some of the skin and mucus membrane. The surgeon picks up the upper edge of the incised posterior vaginal wall and applies two Kelly clamps, for purposes of traction. These clamps are held firmly downward as he advances a pair of scissors, with the points uppermost, beneath the vaginal epithelium separating it from the underlying muscle. A good cleavage plane is thus established and the dissection continues upward toward the cervix in an avascular plane. A finger is then introduced into this opening and the vaginal epithelium is divided in the midline. The rectum and scar tissue are thus separated from the vagina. At this time if there is a rectocele present a wedge-shaped piece of posterior vaginal wall is removed and a Kelly clamp is placed at the new apex. Allis clamps are placed on either side of the vaginal epithelium. The rectum is seen high up covered with a thin film of fascia. This can be dis-

amputated cervix, and out through the vaginal mucosa about 2 cm. above the edge of mucous membrane. A similar needle is threaded on the other loose end of the suture and the above maneuver repeated, bringing out this end of the suture approximately 2 cm. away from the other end. The same maneuver is repeated posteriorly.

To close the lateral angle a so-called crown stitch is placed at each corner (Fig. 20-7). This stitch of No. 0 catgut passes through the anterior

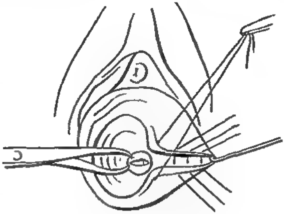

Fig. 20-7 The crown stitch has been introduced on the left passing into and out of the cervical canal at the angle. The obliterating sutures have been placed in the left lateral angle

vaginal mucosa into the substance of the cervix, emerging in the endocervical canal. Continuing the suture in the opposite direction the stitch passes from the canal through the cervix to emerge on the posterior vaginal wall at the corner. This suture is repeated at the opposite corner.

By tying the first two sutures placed, the vaginal mucosa is drawn up into the canal Ligation of the two lateral sutures will complete the epithelization so important to the success of the operation. The two edges in the new canal are now completely covered with mucosa.

The lateral cut edge of vaginal flap is placed on tension with an Allis forcep and the denuded edges of the anterior and posterior vaginal mucosa are approximated by a suture of interrupted catgut which includes a portion of the paracervical tissue. In this manner dead space is obliterated. The same maneuver is repeated on the opposite angle.

The operation is completed by passing a sound into the newly formed cervical canal to determine its patency.

It is not essential that the removal of the cervix be carried as high as the level of the internal os. The amount of cervix to be removed may be left to the discretion of the operator.

EXCISION OF BARTHOLIN'S CYST AND ABSCESS OF BARTHOLIN'S GLAND

Indication. Bartholin's cysts are of themselves innocuous. However, such cysts may become infected, may interfere with intercourse, and are known occasionally to develop into malignant tumors. For these reasons the Bartholin's cyst is best removed and in its cystic state it is very easy to excise. When a Bartholin's cyst becomes infected the procedure of incision

and drainage is the primary consideration and is a definite indication for its ultimate removal.

Operation. An incision is made through the skin over the cyst and the cyst wall is exposed. With sharp knife dissection the cyst is completely excised from its bed. A considerable amount of bleeding may be encountered from vessels, especially in the upper end of the wound. The cyst should be removed in toto. Then the dead space is obliterated by catgut sutures and a small wick placed into the cavity just before the skin is closed. The closure of the skin can be done by means of catgut or silk sutures.

An acute abscess of Bartholin's gland is best treated by incision and evacuation of the pus. The cavity is then packed with thin strips of iodoform gauze. At the end of four days the abscess and the inflammation have subsided; the gauze is then withdrawn and under anesthesia, with the index finger in the cavity, the dissection of the cyst wall is carried out as described.

SIMPLE PERINEORRHAPHY AND REPAIR OF RECTOCELE

Indications. Indications for repair of the perineum are numerous. Most important is the anatomic reconstruction necessary following total abdominal hysterectomy or vaginal hysterectomy where the pelvic floor is reconstructed. The well-repaired and solid perineum takes the strain off the new peritoneal floor as pressure pushes the peritoneum downward.

Rarely is the operation carried out as the only vaginal procedure, for defects in the posterior vaginal wall of themselves give rise to symptoms infrequently. It is used in conjunction with other procedures such as cystocele repair, or Donald-Fothergill operation where reapproximation of the levators and reduction of the rectocele provides additional pelvic support.

The difference between simple perineorrhaphy and rectocele is largely a question of extent of separation of normal tissues. In simple perineorrhaphy the levator muscles separate at the perineal body. Where rectocele is present the separation is more pronounced as the rectum bulges out into the vagina through the defect.

Operation. Allis clamps are applied at the point of exit of Bartholin ducts and traction is applied laterally by the assistants. The tissue between the clamps is excised including the scar and some of the skin and mucus membrane. The surgeon picks up the upper edge of the incised posterior vaginal wall and applies two Kelly clamps, for purposes of traction. These clamps are held firmly downward as he advances a pair of scissors, with the points uppermost, beneath the vaginal epithelium separating it from the underlying muscle. A good cleavage plane is thus established and the dissection continues upward toward the cervix in an avascular plane. A finger is then introduced into this opening and the vaginal epithelium is divided in the midline. The rectum and scar tissue are thus separated from the vagina. At this time if there is a rectocele present a wedge-shaped piece of posterior vaginal wall is removed and a Kelly clamp is placed at the new apex. Allis clamps are placed on either side of the vaginal epithelium. The rectum is seen high up covered with a thin film of fascia. This can be dis-

sected off the lateral vaginal wall. It is then resutured in front of the rectum with an interrupted or continuous atraumatic catgut suture. This step reduces the rectocele but is not of itself sufficient.

The levator muscles must be restored to their normal position in front of the rectum. This is the simple perineorrhaphy. It completes the operation of rectocele repair but is often used when there is no rectocele present but only weakness of the perineal body.

A heavy needle threaded with No. 0 catgut pierces deeply into the left levator ani muscle and then into the right levator muscle. Three interrupted sutures are placed one above the other and held in clamps, to be tied later. The vaginal epithelium is closed from above downward toward the orifice using either interrupted or continuous sutures. At the fourchette, sutures of No. 00 chromic catgut are placed into the perineal body. The sutures in the levator ani muscles and perineal body are then tied. The skin edges are approximated with No. 00 catgut.

REPAIR OF THIRD DEGREE TEAR OR LACERATION OF THE SPHINCTER ANI MUSCLE

Indications. The indications for repair of the torn sphincter ani muscle are obvious. Such a tear gives the patient partial incontinence of feces and frequently complete lack of control of gas. Diarrhea is very disagreeable, for the imperfect anal system cannot control the escape of watery feces.

Operation. This operation is carried out just as is a perineorrhaphy, and atraumatic sutures are introduced into the submucosa and the rectal wall tear is closed without the sutures entering the inside of the gut. If the sphincter ani is torn a figure-of-eight suture is introduced starting in the left side of the torn sphincter ani and sutured deeply into the right sphincter ani and then across to the left sphincter ani again, and then to the right and tied. It facilitates the operation if nerve hooks are placed into the ends of the sphincter muscle so as to bring them up out of the depths of the wound as the sutures are placed. The closure of the perineum then proceeds with the approximation of the levator ani muscles over the sutured rectum. Care must be taken to carry the suture in the mucous membrane of the rectum and anus out to the outside and up into the skin of the anus. Interrupted sutures are best

URETHROCELE, CYSTOCELE, AND UTERINE PROLAPSE

Inasmuch as all three of these conditions represent varying degrees of hernia formation and frequently exist as sequelae from childbirth, the surgical repair of these entities should be considered together.

The symptoms associated with relaxation of the anterior vaginal wall vary markedly. Some patients with extensive cystocele formation do not appear to be especially troubled while others are frequently troubled with less obvious pathology. Urgency, frequency, and incontinence of urine—the latter occurring as intra-abdominal tension is increased during the acts of laughing, coughing, sneezing, or straining—are the most common of the symptoms. Patients complain of bearing down and a sense of lack of pelvic

support to a far greater extent than they do from posterior wall relaxation. Backache is not uncommon, and mild attacks of cystitis are often present, depending on the degree of urinary retention. Stress incontinence, as noted above, is far more likely to occur where either a urethrocele or a moderate cystocele is present, than with a formidable prolapse. Special operations of a great variety but basically similar have been devised for the correction of this situation.

Choice of Operations. In addition to the choice of the proper operation to fit the particular symptom complex for the presenting difficulty, it is also essential to consider the patient's age and desire for future childbearing. This factor must be considered in the more extensive degrees of prolapse. Thus, for example, in the childbearing age one may prefer to perform the Manchester (Donald or Fothergill) type of operation rather than a vaginal hysterectomy. In the postmenopausal group the vaginal hysterectomy is generally preferred, with the Le Fort procedure performed in patients who present a less favorable surgical risk.

Whatever operation is chosen, the basic maneuver common to all is the advancement of the bladder off the cervix. For this reason the operative procedures will be discussed in the following order: repair of cystocele, including the Kennedy procedure; Manchester operation; vaginal hysterectomy.

Inasmuch as the problem of stress incontinence is a varied one the operations for the correction of this difficulty will be considered after the description of the procedures designed to correct the prolapse. Here too the basic maneuver involves the bladder advancement operation.

REPAIR OF CYSTOCELE

Indications. The sagging anterior vaginal wall may produce symptoms of cystitis, bearing-down sensations, urinary frequency or incontinence. Repair of this type of hernia is then warranted. In most instances the bulging mass is apparent but, where symptoms exist in the absence of obvious pathology, the actual presence of a cystocele may become more evident when the patient is examined in the standing position.

The amount of residual urine and the degree of cystitis should be determined before attempting operative repair. Bladder irrigations with 1:5,000 silver nitrate solution or a course of sulfonamide therapy may be indicated before or in conjunction with surgery.

While the operation may be performed under local anesthesia if necessary, spinal or gas-oxygen-ether anesthesia are the agents of choice.

Technic. To aid in exposing the field, a suture is passed through the mucous membrane of the vestibular area of the vagina and through the skin lateral to the labia majora. The latter will be drawn out of the way when these sutures are tied.

A tenaculum is then placed on the cervix, and pushing the cervix upward reveals the distal-most fold of redundant bladder tissue. The vaginal wall incision is made distal to this fold in a semicircular fashion with the cervix in firm downward traction (Fig. 20-8). This incision is about 2 cm. above the external cervical os. The assistant continues downward traction while

the surgeon picks up the superior cut edge of the vaginal epithelium. A small nick is made directly underneath the mucosa with the tip of the dissecting scissors, and a relatively bloodless line of cleavage is established by alternately opening and closing the scissor blades. The tips of the scissors should be held upward exerting pressure on the under surface of the vaginal wall. This plane of cleavage is thus carried up to the urethral meatus. A longitudinal midline incision is made in the mucosa from this point down to the transverse circular incision below. A shaggy, red, fascia-like layer will then be seen overlying the bladder wall.

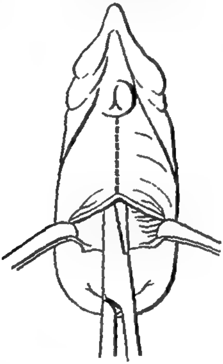

Fig 20-8 A transverse incision has been made above the external os. The open blade of the scissors has established a plane of cleavage beneath the vaginal mucosa and will be continued to the level of the urethra.

Kelly clamps are then placed about one inch apart on the right cut edge of the vaginal wall. The latter is placed on constant flat lateral traction, and the uterus on constant downward traction by the operator or second assistant (Fig. 20-9). Careful inspection of the exposed epithelium will reveal the presence of blood vessels in the underlying fascia-like layer. It is this layer which is separated from the mucosa by sharp and blunt dissection. The proper plane of cleavage is produced, and bleeding is avoided. The knife handle is a good instrument to complete the separation which is enhanced by the operator if he will place a gauze sponge on the bladder and place it on lateral countertraction. It will be noted that this connective tissue is separated from the vaginal mucosa and not from the bladder (Fig. 20-10). It is in this layer that the blood vessels lie. Injury to the bladder is therefore easily avoided.

Once this line of cleavage is established it is carried upward alongside the urethra. A plexus of veins is encountered here, and it should be visualized. Employing the same maneuver these vessels can be made to go with the urethra without damaging them Occasionally they should be isolated

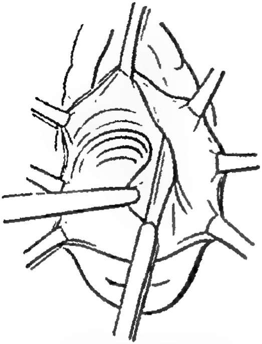

Fig 20-9 The most important step involves the establishment of the proper fascial plane. The vaginal fascia can be seen attached to the vaginal mucosa as it is held on tension. By counter traction with forceps a flat surface permits the use of a sharp knife in an obliquely posterior manner to separate the bladder fascia from that of the vaginal mucosa

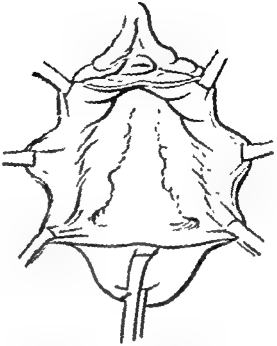

Fig 20-10 The fascia attached to the bladder in the central defect is evident after the dissection of Figure 20-9.

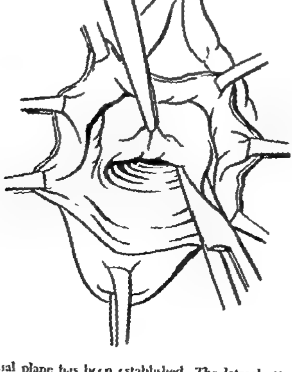

Fig 20-11 The fascial plane has been established The lateral attachments of the bladder fascia to the cervix are about to be divided

the surgeon picks up the superior cut edge of the vaginal epithelium. A small nick is made directly underneath the mucosa with the tip of the dissecting scissors, and a relatively bloodless line of cleavage is established by alternately opening and closing the scissor blades. The tips of the scissors should be held upward exerting pressure on the under surface of the vaginal wall. This plane of cleavage is thus carried up to the urethral meatus. A longitudinal midline incision is made in the mucosa from this point down to the transverse circular incision below. A shaggy, red, fascia-like layer will then be seen overlying the bladder wall.

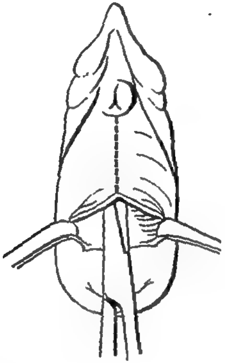

Fig. 20-8. A transverse incision has been made above the external os. The open blade of the scissors has established a plane of cleavage beneath the vaginal mucosa and will be continued to the level of the urethra.

Kelly clamps are then placed about one inch apart on the right cut edge of the vaginal wall. The latter is placed on constant flat lateral traction, and the uterus on constant downward traction by the operator or second assistant (Fig 20-9). Careful inspection of the exposed epithelium will reveal the presence of blood vessels in the underlying fascia-like layer. It is this layer which is separated from the mucosa by sharp and blunt dissection. The proper plane of cleavage is produced, and bleeding is avoided. The knife handle is a good instrument to complete the separation which is enhanced by the operator if he will place a gauze sponge on the bladder and place it on lateral countertraction. It will be noted that this connective tissue is separated from the vaginal mucosa and not from the bladder (Fig. 20-10). It is in this layer that the blood vessels lie. Injury to the bladder is therefore easily avoided.

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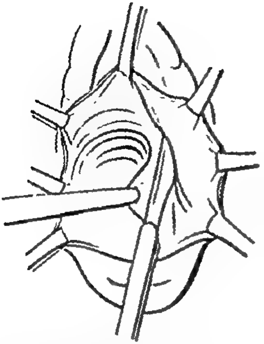

Fig 20-9. The most important step involves the establishment of the proper fascial plane. The vaginal fascia can be seen attached to the vaginal mucosa as it is held on tension. By counter traction with forceps a flat surface permits the use of a sharp knife in an obliquely posterior manner to separate the bladder fascia from that of the vaginal mucosa.

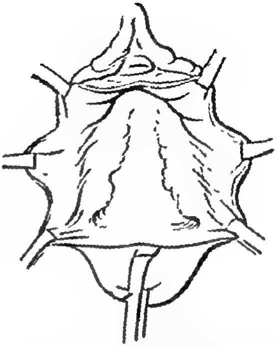

Fig 20-10. The fascia attached to the bladder in the central defect is evident after the dissection of Figure 20-9.

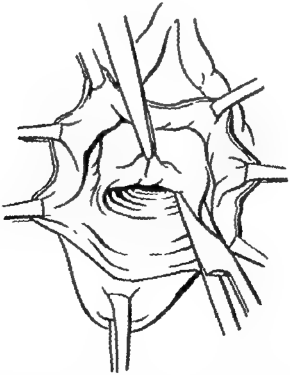

Fig 20-11. The fascial plane has been established. The lateral attachments of the bladder fascia to the cervix are about to be divided.

the surgeon picks up the superior cut edge of the vaginal epithelium. A small nick is made directly underneath the mucosa with the tip of the dissecting scissors, and a relatively bloodless line of cleavage is established by alternately opening and closing the scissor blades. The tips of the scissors should be held upward exerting pressure on the under surface of the vaginal wall. This plane of cleavage is thus carried up to the urethral meatus. A longitudinal midline incision is made in the mucosa from this point down to the transverse circular incision below. A shaggy, red, fascia-like layer will then be seen overlying the bladder wall.

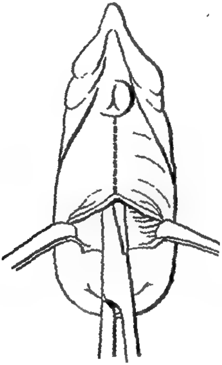

Fig. 20-8 A transverse incision has been made above the external os The open blade of the scissors has established a plane of cleavage beneath the vaginal mucosa and will be continued to the level of the urethra.

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Once this line of cleavage is established it is carried upward alongside the urethra. A plexus of veins is encountered here, and it should be visualized. Employing the same maneuver these vessels can be made to go with the urethra without damaging them. Occasionally they should be isolated

steps are also quite similar or identical in the various operations designed for correction of stress incontinence, as far as exposure is concerned.

Continuing with the repair of the cystocele, a mattress suture is now placed, by means of a cervical needle, through the fascia layer on each side to close the top of the urogenital diaphragm lying beneath the urethra (Fig. 20-12). Two sutures generally are sufficient to effect this closure (Fig. 20-13). The fascial flaps are then sutured together with interrupted chromic catgut sutures (Fig. 20-14). The vaginal wall is placed on tension and the excess tissue is trimmed. If the patient is in the active sexual age group, it is unwise to sacrifice much vaginal wall. Interrupted chromic catgut sutures which occasionally incorporate the underlying fascial layer to obliterate the dead space are used to complete the closure (Fig. 20-15).

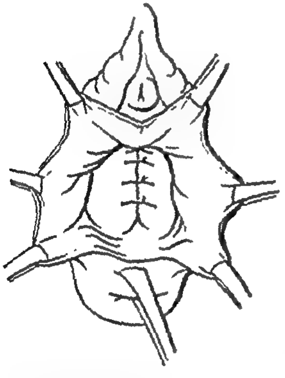


Fig. 20-14. The defect in the bladder fascia has been corrected by as many interrupted sutures as are needed.

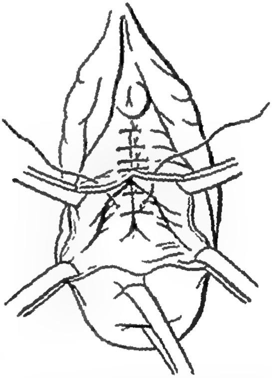


Fig. 20-15. The final closure of the vaginal mucosa is indicated with attachment to the underlying bladder fascia to eliminate dead space.

KENNEDY REPAIR FOR STRESS INCONTINENCE

Indications. Stress incontinence may be so incapacitating that the patient retires from social contacts because of her discomfort and embarrassment. The symptoms are those of involuntary loss of urine following any increase in intra-abdominal tension, such as laughing, coughing, or sneezing. Frequently the patient has to wear a constant pad for protection against urinary loss. The basic defect seems to be at the neck of the bladder. Marked degrees of prolapse of the uterus or bladder may be present without stress incontinence. In most instances only a very mild degree of bladder descent is noted. A number of tests are devised to demonstrate the presence of stress incontinence. The patient in the lithotomy position should be

and ligated. Once this separation has been done, an empty space lateral to the urethra is found which will admit the tip of the examining finger. The lateral attachments of the urethra have now been freed, and the same procedure is then carried out on the patient's left side.

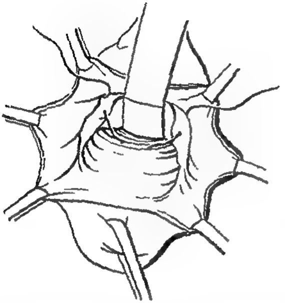


Fig 20-12. The bladder has been advanced upward after sectioning the lateral attachments of the bladder The initial suture has been applied at the top of the urogenital diaphragm.

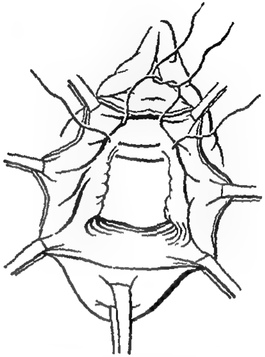


Fig. 20-13. The remaining sutures closing the defect in the urogenital diaphragm over the urethra are in position.

The bladder remains attached to the cervix, and its lower border must be identified before separation of these two structures is begun (Fig. 20-11). To avoid bladder injury a probe may be introduced into the urethra to determine the bladder's distalmost fold. With continued downward traction on the uterus by an assistant, the bladder is picked up with forceps or pushed upward by the operator with a sponge. This maneuver is begun in the relatively avascular midline. As the bladder is freed from the cervix, the lateral bladder attachments will stand out as two pillars connecting the bladder and cervix. These frequently contain small blood vessels which are clamped, divided, and tied close to the cervix. The bladder then continues to be pushed upward off the cervix, and the anterior peritoneal reflection is seen lying along the anterior wall of the uterus.

The bladder advancement procedure has now been completed with a minimum of blood loss and bladder trauma. These steps in the operative procedure are for all operations designed to correct prolapse, except for the Le Fort procedure. It is at this point that the operator decides the procedure of choice. He may open the peritoneal cavity and continue with a vaginal hysterectomy or bring out the fundus of the uterus in front of the bladder as in the interposition operation On the other hand he may perform either a Manchester operation or simply complete the cystocele repair. These

Technic. Inasmuch as the cervix will subsequently be amputated and the vaginal mucosa brought over to cover the new raw surface, the cervical canal should *first* be dilated. This step tends to prevent or minimize the danger of subsequent stenosis which is one of the complications of the operation. Because the uterus is to be left, the surgeon should be assured that the uterine cavity is normal by curettage.

The early steps of the operation follow those employed in the advancement of the bladder. When the lateral bladder attachments, the so-called "pillars," are freed by section the bladder is advanced upward and held in this position by a retractor placed over a protecting wet sponge.

With the uterus held in traction by tenacula, the cardinal ligaments are easily recognized lying on either side of the body of the upper cervix and lower uterus. The uterine vessels lie within them. Interrupted No. 1 chromic catgut sutures are placed here starting at the base, from the left and continued over the cervix through the right cardinal ligament (Fig. 20-16).

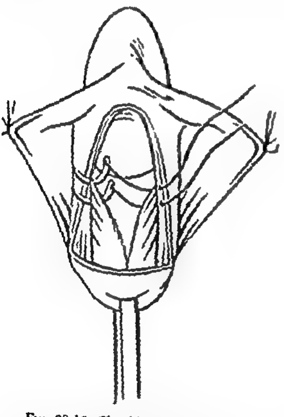


Fig. 20-16. The bladder fascia has been exposed and the bladder advanced off the cervix as seen in Figures 20-8 to 20-12. The interrupted sutures have been placed in the so-called cardinal ligaments before amputation of the cervix.

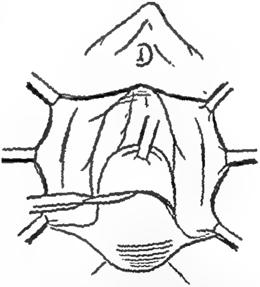


Fig. 20-17. The cervix has been placed on traction in direction of the urethra to expose the posterior wall of the cervix while the posterior transverse incision is made.

The number of sutures required depends on the degree of relaxation of these perivascular sheaths. The sutures are tightened to determine the number required to accomplish this, but they are not tied until after the amputation of the cervix is performed. Usually four sutures suffice. The placement of these sutures is the most important step in the operation for it is the reapproximation of the cardinal ligaments in front of the cervix that corrects the prolapse.

urged to strain. Urine can often be seen squirting from the urethra. If two fingers are placed in the vagina on either side of the urethra and the neck of the bladder elevated, straining on the part of the patient will not then produce urinary loss as it had formerly. Repair of the neck of the bladder is then indicated. A number of operations are designed to correct the defect. The Marshall-Marchetti operation will be described in the section on abdominal procedures (page 866). The simplest, commonest, and often the most effective operation for correction is the Kennedy repair.

Technic. The Kennedy repair for stress incontinence corrects the sagging bladder neck in the following fashion:

After the bladder is advanced as just described, it is brought into view by downward traction, exposing the full length of the urethra. The first of a series of interrupted atraumatic sutures passes into the paraurethral tissue at the bladder neck on the left, and carries across the body of the urethra to enter a corresponding area on the right. The urethral lumen and the bladder must not be entered. Several such infolding sutures are placed, infolding any urethral redundancy and deliberately reducing the caliber of the urethra. These are the basic sutures in the Kennedy repair.

The cystocele is corrected by three or four shallow mattress sutures placed in the bladder wall on either side of the midline. The excess vaginal mucosa is trimmed away. To help support the urethra the vaginal wall will now be fixed to the under side of the pubic rami with fine wire sutures.

Avoiding the bladder, the suture is first introduced from the vaginal side about one-half inch from the edge of the incision. The vaginal flap is held up, the bladder protected from the needle, and the suture is passed through the periosteum of the pubis. The same suture is then brought out through the vaginal wall a short distance from the previous point of entrance. Two more wire sutures are placed lateral to this one, and the same procedure is carried out on the other side. The vaginal mucosa is closed in the usual fashion. The ends of the wire sutures are twisted together, snugging the vagina up in place, and small lead shot are squeezed over their ends for protection.

MANCHESTER (DONALD OR FOTHERGILL) OPERATION

Indications. A woman in the childbearing age who desires more children and who has a uterine prolapse to the introitus may be considered a good candidate for this procedure. The symptoms generally consist of a bearing-down sensation with low abdominal ache and backache, and a feeling as though "something were coming down." Childbearing is possible following the operation, generally without serious complication, though the obstetrician may elect to perform a Cesarean rather than run the risk of disrupting the previously repaired pelvic floor.

To avoid pelvic infection the cervix should be made clean by preoperative antibiotics, cauterization, and so on. When procidentia is present, the majority of American surgeons favor vaginal hysterectomy.

The sole supporting element comes from the connective perivascular tissue at the base of the broad ligaments, firmly attached to the lateral aspects of the cervix and often referred to as the cardinal ligaments.

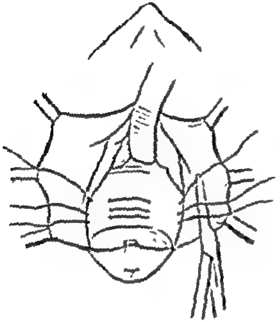


Fig 20-20 The posterior Sturmdorf stitch has been completed

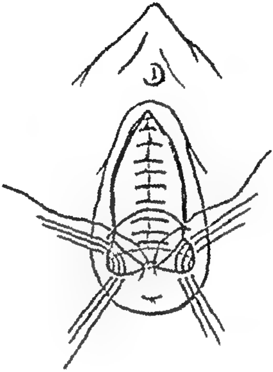


Fig 20-21 The sutures in the cardinal ligament have been ligated and the defect in the bladder fascia closed with interrupted sutures The anterior Sturmdorf and the lateral sutures are in position.

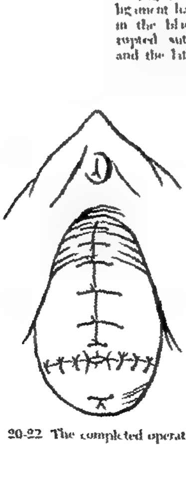


Fig 20-22 The completed operation

Before the cervix can be amputated the vaginal epithelium must be stripped from the posterior cervical wall beyond the point chosen for amputation. This flap of vaginal wall is to be used to cover the raw edge of the amputated cervix and must be drawn into the cervical canal to lie easily without tension. The flap must thus be mobilized widely enough on all sidés to accomplish this. This is accomplished by holding the tenaculum upward toward the cervix to expose the posterior cervical wall. A circular incision is made through the vaginal epithelium connecting the two cut edges of the vaginal wall anteriorly (Fig. 20-17). The vaginal wall is then stripped off the cervix with scissor or knife dissection as far as need be.

A point of amputation is elected to permit approximately three inches of uterus to remain (Fig. 20-18). Inasmuch as the cervix is always elongated at the expense of the fundus in prolapsus uteri the level is usually at the level of the internal os. A circular amputation is performed, making no attempt to cone out the cervix. Before amputation is completely accomplished a tenaculum is placed on the cut uterine edge for continued traction. The previously freed vaginal mucosa falls into place over this raw surface by utilizing the modified Sturmdorf stitch anteriorly and posteriorly (Fig. 20-19). (This stitch has been previously described for amputation of the cervix, page 835.)

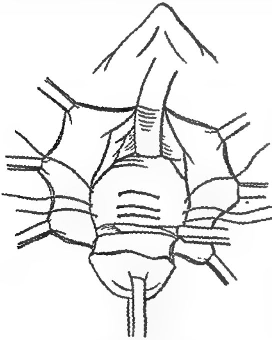


Fig 20-18 With the sutures placed in the cardinal ligaments the amputation of the cervix is begun

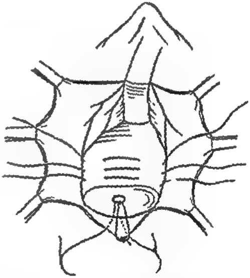


Fig 20-19. With the cervix amputated the posterior Sturmdorf stitch has been placed in the posterior vaginal mucosa.

The stitch is passed through the posterior layer near the midline and is loosely tied with the ends left long. A curved cutting needle is threaded on each end and passed from within the canal, through the cervix, and out on the mucosa, approximately 2 cm. from the cut edge and about one-quarter inch apart. Tying this suture will completely cover the posterior edge of the cervix (Fig. 20-20).

The operation is greatly facilitated by constant traction on the cervix by a tenaculum (Fig. 20-23). With the bladder advanced off the cervix (Fig. 20-24) and the anterior peritoneal fold exposed, attention turns to the posterior uterine wall. The cervix is held in upward traction and the posterior wall of the cervix and vagina are exposed. The vaginal mucosa on the back of the cervix is transected at the level of the initial anterior incision (Fig. 20-25). This is stripped off the cervix, producing minimal bleeding if kept in the proper cleavage plane. The separation is continued upward until the uterosacral ligaments stand out well on either side, with the peritoneum of the cul-de-sac appearing between them.

Fig. 20-23 The cervix of the prolapsed uterus placed on traction by a tenaculum. The transverse incision in the anterior vaginal mucosa is outlined.

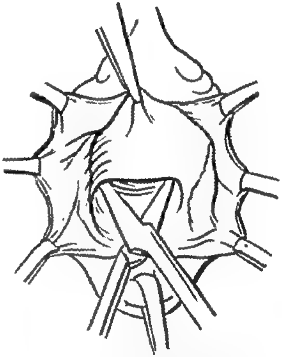


Fig. 20-24 Putting the bladder on traction by forceps drawing the bladder wall toward the urethra, the proper cleavage plane between the bladder and the cervix is established. Stay on the uterine side.

The peritoneum is incised, and it may be sutured to the wall of the posterior vaginal mucosa to reduce blood loss. The index finger is then inserted into the peritoneal cavity to make certain that the uterosacral ligaments are not adherent to other structures. These ligaments are then included in individual stitch ligatures. The tissue is then divided and the sutures are clamped with a straight snap and left long. These sutures will later be retrieved and used in the final reconstruction of the pelvic floor.

Covering the anterior lip is less easily accomplished due to the longitudinal mucosal incision which creates two angular flaps. The true Sturmdorf stitch is best adapted for this. It utilizes a single suture which is begun through the anterior vaginal mucosa on the left side, near the midline and about 1 5 cm. from the cut edges (Fig. 20-21). It then passes deeply through the substance of the cervix emerging within the endocervical canal, over the face of the cervix and back up through the same side of the vaginal wall, emerging near the edge at the angle. It is carried over to the other side and continued in exactly the reverse manner. When the two ends are tied the vaginal wall flaps will be drawn into the cervical canal. The suture is now loosened to allow the sutures in the cardinal ligaments to be tied, beginning with the most distal suture. Thus the tissue from the two sides is brought together in front of the uterus. This will force the uterus upward and bring the uterus into anteflexion. The extent to which the uterus is suspended can now be tested by applying traction to the tenaculum. The Sturmdorf suture is now tied.

The edges of the vaginal fascia overlying the bladder are approximated with interrupted catgut sutures advancing the bladder. The most distal suture includes the uterus. The excess of vaginal wall is trimmed off and the edges approximated with interrupted sutures (Fig. 20-22). Too much vaginal wall should not be sacrificed when subsequent childbearing is anticipated.

A perineorrhaphy or rectocele repair is then carried out in the usual manner. An adequate vaginal orifice must be preserved. If the perineorrhaphy is carried too high, the upper part of the vagina will be constricted. If done too low, the redundant tissue of the upper portion will roll out over the lower constricted area.

An inlying Foley catheter is placed in the bladder and connected to a constant drainage apparatus. Occlusion of the cervix will rarely occur if the cervix is sufficiently dilated during the operation. It is well to have the patient return to the office for dilatation in anticipation of the next few menses.

VAGINAL HYSTERECTOMY

Indications. This operation will always be popular because of the low mortality and morbidity rate, and it is particularly effective in older women with prolapse or procidentia. If the patient is a poor surgical or anesthetic risk, local anesthesia may be employed.

Contraindications. While the surgeon trained in the technic of this approach may be able to remove large uterine tumors, the operation represents a contraindication to all but the specialist. Likewise it is contraindicated where previous pelvic surgery has been done, the uterus suspended, or where there is coexisting pelvic inflammatory disease or endometriosis. It is an unsatisfactory cancer operation, particularly if the adnexae are involved or should be removed, as in carcinoma of the body of the uterus.

Technic. The bladder should be emptied by catheter, the uterus thoroughly curetted, and the bladder advanced away from the cervix and uterus (as previously described).

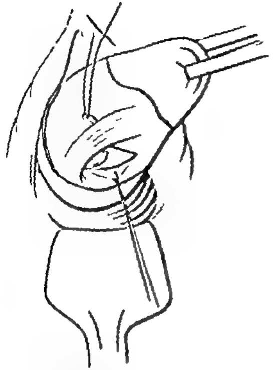


Fig 20-27. The posterior cul-de-sac has been incised and the peritoneum entered. The uterus is drawn to the left, exposing the right cardinal ligament. By directing the suture with a finger in the cul-de-sac the right cardinal ligament is sutured.

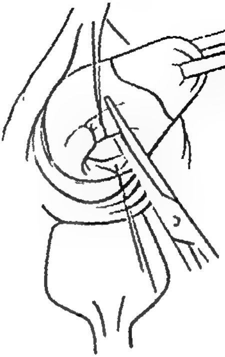


Fig 20-28. A double ligature is applied and the ligament divided.

Fig 20-29. The tenaculum then draws the uterus toward the peritoneum, exposing the anterior uterine wall. The bladder has been advanced upward. The anterior fold of peritoneum has been exposed and the peritoneum opened.

Fig. 20-25 The posterior circular incision has been made on the cervix, the vaginal mucosa stripped back, and the cul-de-sac exposed and opened transversely. To minimize the bleeding the posterior leaf of peritoneum has been sutured to the cut edge of the vaginal mucosa.

Fig. 20-26. The cervix is drawn toward the symphysis and the cul-de-sac opened under the direction of a gloved finger. In the cul-de-sac a clamp has been placed on the right uterosacral ligament. This will be sectioned and sutured

The uterus is placed on traction in a downward direction to the left so that the cardinal ligament on the right side stands out clearly (Fig. 20-27). It is at this point that the ureters may be injured, for they tend to describe a downward loop just before they turn upward to enter the bladder. With the uterus pulled to the side and the cardinal ligament under direct vision the index finger is inserted as a guide to the placement of a stitch ligature. This is placed close to the uterus and parallel with it. Slight relaxation in traction on the uterus is advisable to prevent retraction of the divided vessel out of the ligature as it is being tied. This suture is also clamped and held long, on tension, as a second stitch ligature is placed (Fig. 20-28). The ligament is then divided and the sutures cut. The same procedure is carried out on the left side.

The anterior peritoneal fold is identified by inserting the index finger into the peritoneal cavity behind the uterus over the top of the fundus. The bladder is retracted and protected by a small Deaver retractor placed over wet gauze. The peritoneum is grasped with forceps and incised (Fig. 20-29).

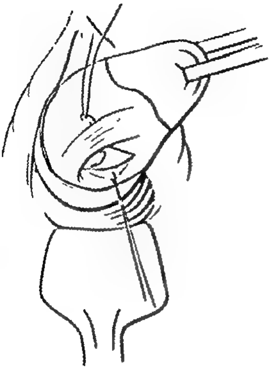


Fig 20-27. The posterior cul-de-sac has been incised and the peritoneum entered The uterus is drawn to the left, exposing the right cardinal ligament By directing the suture with a finger in the cul-de-sac the right cardinal ligament is sutured

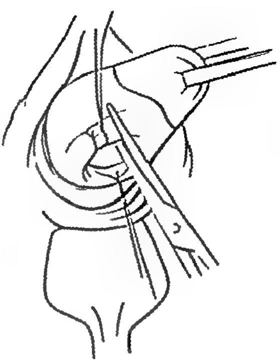


Fig 20-28 A double ligature is applied and the ligament divided.

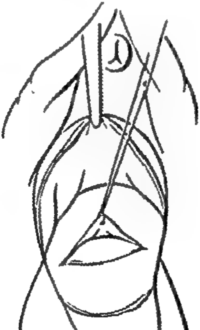


Fig 20-29 The tenaculum then draws the uterus toward the peritoneum, exposing the anterior uterine wall The bladder has been advanced upward The anterior fold of peritoneum has been exposed and the peritoneum opened

An identifying suture is placed on the peritoneal edge. The retractor is shifted to the interior of the abdominal cavity and the bladder again held out of the way. A finger is introduced into the peritoneal cavity and swept laterally on either side to explore for adnexal or other pelvic pathology. The fundus is delivered through this opening and held on downward traction by a double hook tenaculum (Fig. 20-30). A finger is placed behind the left tube and ovarian ligament to prevent damage to prolapsed bowel and a stitch is passed through these structures. This is tied and held long..A Kelly clamp is placed across the tube and ligament on the uterine side, the structures cut, and the stump immediately clamped and resutured, thus placing two ties on the ovarian vessels (Fig. 20-31). The ends are then cut.

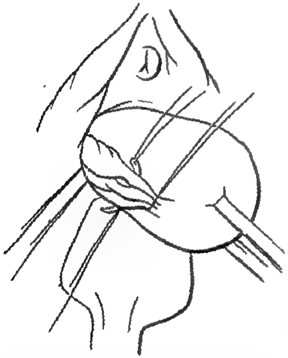


Fig. 20-30. The fundus of the uterus has been grasped by a tenaculum and pulled through the rent in the anterior peritoneum The right ovarian vessels are exposed and the first sutured and tied as the second is applied

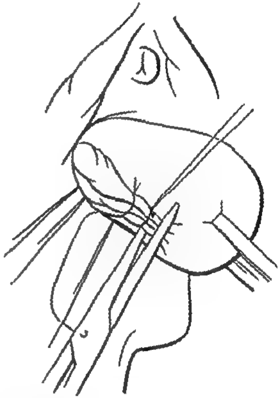


Fig 20-31. The ovarian vessels on the right have been doubly ligated and are about to be divided.

The uterus is held on traction to the left and the clamp on the proximal stump is reapplied to include the round ligament. A suture is placed through this structure, the ligament cut between the clamp and suture, and the suture held long in a curved snap for future use in supporting the vaginal cuff.

Dissection may continue downward as with an abdominal hysterectomy, or upward if the uterus is fixed by other pathology. The ureter is close to the uterine vessels, and proper exposure is absolutely necessary. The operator may continue on one side, or repeat each step on both sides. The vaginal wall is stripped back laterally, exposing the uterine vessels and producing lateral retraction of the ureter. A single clamp is placed close to

the uterus on the broad ligament to control the ovarian branch of the uterine artery. The tissue between the clamp and uterus is cut and ligated. The uterine vessels are now well isolated from the surrounding tissue. The vessels are doubly clamped and the tissue severed between them, leaving a cuff in the lateral clamp. Another clamp is placed on the cuff, and a stitch ligature placed about the vessel lateral to the clamps and tied as the first of the clamps is removed. The second clamp acts as a control should the first tie break. A second stitch is placed about the vessels and tied.

The tissue remaining on the left contains the cervical branch of the uterine artery, which is clamped, severed, and sutured.

The same steps are carried out on the right side, and the uterus is removed.

The peritoneal edges are approximated in the center by an atraumatic suture after identifying the edges by the previously placed ties (Fig. 20-32).

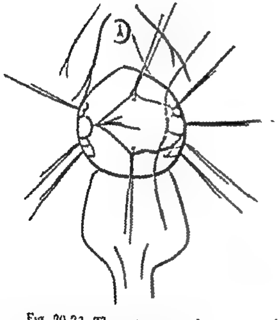


Fig. 20-32 The sutures on the stumps of the broad and round ligaments have been left long. The peritoneal edges are about to be approximated.

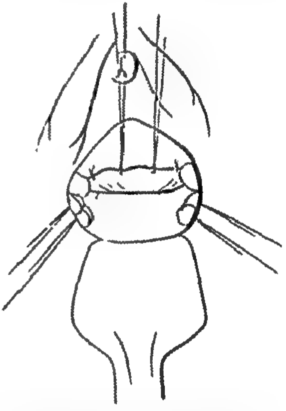
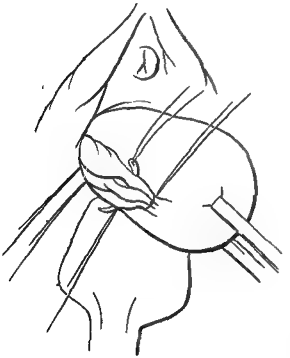


Fig. 20-33 The peritoneum has been closed. The stumps of the cut edges of the ligaments can be seen emerging extraperitoneally from the corners of the sutured peritoneum.

The central suture is held on left lateral traction and the peritoneal edges are closed by interrupted stitches, bringing the round and uterosacral ligaments out through the lateral angle. The central suture is then placed on right lateral traction and closure continues as on the other side.

A stitch is passed through the round and uterosacral ligaments on the left, passing up through the round ligament again, tied, and left long (Fig. 20-33). The same maneuver is carried out on the other side. The cystocele

An identifying suture is placed on the peritoneal edge. The retractor is shifted to the interior of the abdominal cavity and the bladder again held out of the way. A finger is introduced into the peritoneal cavity and swept laterally on either side to explore for adnexal or other pelvic pathology. The fundus is delivered through this opening and held on downward traction by a double hook tenaculum (Fig. 20-30). A finger is placed behind the left tube and ovarian ligament to prevent damage to prolapsed bowel and a stitch is passed through these structures. This is tied and held long. A Kelly clamp is placed across the tube and ligament on the uterine side, the structures cut, and the stump immediately clamped and resutured, thus placing two ties on the ovarian vessels (Fig. 20-31). The ends are then cut.



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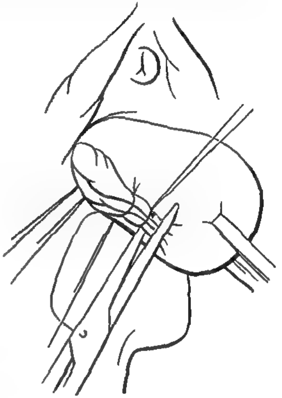

Fig 20-31 The ovarian vessels on the right have been doubly ligated and are about to be divided.

The uterus is held on traction to the left and the clamp on the proximal stump is reapplied to include the round ligament. A suture is placed through this structure, the ligament cut between the clamp and suture, and the suture held long in a curved snap for future use in supporting the vaginal cuff.

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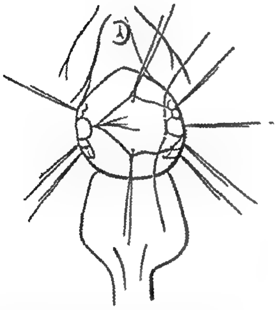
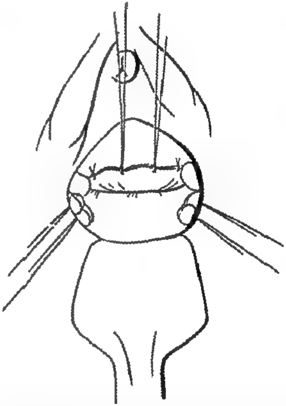


Fig. 20-32 The sutures on the stumps of the broad and round ligaments have been left long The peritoneal edges are about to be approximated



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A stitch is passed through the round and uterosacral ligaments on the left, passing up through the round ligament again, tied, and left long (Fig. 20-33). The same maneuver is carried out on the other side. The cystocele

repair is then carried out, as previously described, and the excess vaginal *mucosa is excised. A needle is placed on one end of the suture, holding the* left uterosacral and round ligaments together, and is passed through the posterior vaginal wall approximately one-half inch from the cut edge. This is also done on the other loose end, and also on the opposite side. All ends are left long. The vaginal mucosa is approximated by interrupted sutures. The untied ends of the ligament sutures are now tied and the apex of the vagina is retracted upward as the ligaments retract.

A perineorrhaphy or rectocele repair is then performed to produce better pelvic support. An inlying Foley type catheter is placed in the bladder.

THE LE FORT OPERATION

Indications. The procedure of choice for vaginal and uterine prolapse is vaginal hysterectomy. Many older women may not be able to withstand the vigors of this degree of surgery, even though it be the vaginal approach. The Le Fort procedure is particularly useful in this group for it can easily be performed under local anesthesia. The blood loss is minimal. It should

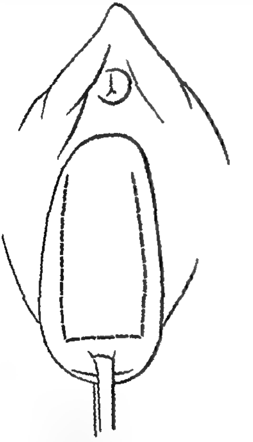

Fig. 20-34 The cervix is held in traction while the quadrilateral area to be denuded from the anterior vaginal wall is outlined.

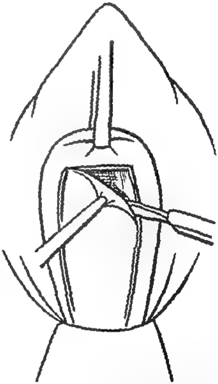

Fig. 20-35. The vaginal mucosa of the posterior quadrilateral outline is elevated and the mucosa stripped to the perineal body.

not be employed if there is any suggestion of a malignant history, nor should it be used when *stress incontinence is present. The successive* layer of infolding stitches buries the cervix and fundus so that they are no longer accessible for direct inspection. The infolding sutures likewise tend to pull

down the neck of the bladder, thereby increasing the tendency to stress incontinence.

Technic. The labia are first sutured to the skin laterally to provide exposure. Tying of these sutures on either side provides exposure by getting the redundant labia out of the operative field.

The redundant bladder of the cystocele accompanying the procidentia is retracted upward with a vaginal or Deaver type retractor, exposing the cervix of the prolapsing uterus. A tenaculum is placed on the cervix and drawn down and outward in the axis of the vagina (Fig. 20-34). A semi-

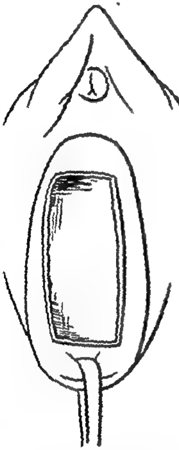

Fig. 20-36 The defect left after denudation of the anterior vaginal wall. There will be a similar defect posteriorly.

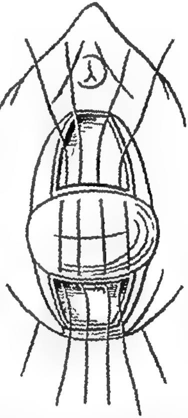

Fig. 20-37 The interrupted sutures from the cut anterior and posterior vaginal mucosa edges are in position. Repeated ligature of these sutures invaginates the cervix.

circular incision is made through the thickness of the vaginal mucosa approximately one-half inch above the cervix on the anterior surface. This incision is carried up on either side of the anterior wall of the urethral meatus. The cut edge of the vaginal mucosa is grasped with clamps or holding forceps by an assistant while the operator exerts countertraction in a downward direction. In this manner the vaginal mucosa is peeled by sharp knife dissection down to the underlying fascia overlying the bladder.

The tenaculum is then pulled in an upward direction toward the urethra while the assistant applies downward traction on the posterior vaginal wall with a Sims type speculum (Fig. 20-35). This exposes the posterior uterine wall. A quadrilateral-shaped denudation is outlined posteriorly, similar to

that of the anterior vaginal surface except that the denudation is carried through the full length of the vagina to a broad base as the perineal body is approached. Clamps are applied to the incised vaginal edge and vaginal mucosa stripped off down to underlying fascia.

Thus two denuded areas exist on the front and back of the prolapsed uterus with normal vaginal mucosa untouched on the lateral sides (Fig. 20-36). Care must be taken to leave enough mucous membrane to cover the cervical canal and to cover the cervix after amputation, if amputation has been considered necessary. It is also very important to leave sufficient mucous membrane on either side of the quadrilateral areas. Thus mucous-membrane-lined tubes are constructed that lead to the cervix or the amputated cervix to permit secretions to find their way to the exterior.

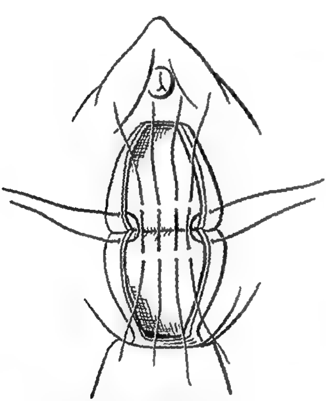

Fig. 20-38. The first layer of sutures has been ligated and the cervix has disappeared. The second layer of sutures has been placed.

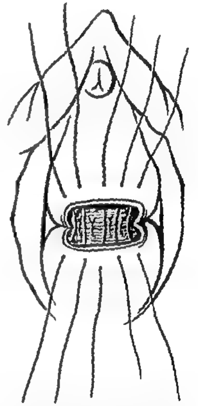

Fig 20-39 The final layer of sutures has been placed as the extent of the denuded area is exhausted

A No. 1 chromic catgut stitch with a smooth needle is placed in the undenuded mucosa of the vagina above the cervix and carried through the same area on the posterior lip (Fig. 20-37). Continuing with interrupted stitches the needle then passes through the edge of the undenuded area on the anterior lip of the cervix further laterally. Three or four such sutures are so placed across the cervix from left to right (Fig. 20-38). Tying of these sutures inverts the cervix. By continuing with successive layers the denuded surfaces are approximated and the invagination of the uterus proceeds (Fig. 20-39). It is essential to suture the raw areas of the anterior vaginal wall to the posterior wall by numerous sutures.

As the perineal body is approached the levator ani muscles are exposed

and approximated in front of the rectum, as done in the classical perineorrhaphy, by several interrupted chromic catgut sutures. The edges of the vaginal mucosa are then approximated (Fig. 20-40). The perineum also can be closed at the completion of the Le Fort operation in the usual manner.

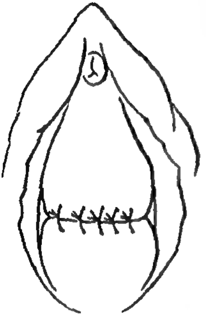

Fig. 20-40. The final layer has been ligated and the raw defect closed

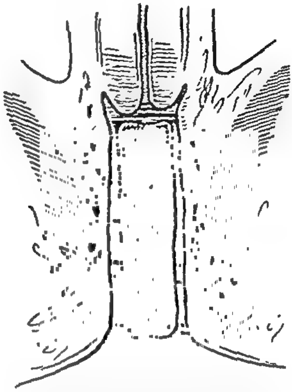

Fig. 20-41. This view shows the advancement upward of the cervix, the closure and the obliteration of the vagina, except for the lateral drainage channels which persist.

When the operation is completed, the denuded areas are completely closed and the uterus completely invaginated, and two free lateral gutters covered with normal vaginal mucous membrane remain (Fig. 20-41).

A Foley type inlying catheter is placed in the bladder to be connected later to a closed irrigation and drainage circuit of the Alcock variety.

ENTEROCELE

Indications. The diagnosis of enterocele is confirmed with the patient lying down in the lithotomy position. The index finger is placed in the rectum within the rectocele while the thumb enters the vagina. The patient is invited to strain downward; as she does so a bulge will appear on top of the finger and beneath the thumb. This observation should be confirmed with the patient in the standing position, when the hernial sac becomes more obvious. This is a true hernia of the posterior vaginal wall. It contains a complete peritoneal sac which seems to take origin from the area between the uterosacral ligament. It is often unrecognized and is regarded as a high rectocele. Simple rectocele repair, however, will not cure, for the individual hernial sac must also be isolated and dealt with, independent of the rectocele repair. Failure to do so will bring recurrence. In most instances

it may be satisfactorily dealt with from the vaginal side. It is possible to repair the defect from above or by a combination of the vaginal and abdominal approaches.

The symptoms are those of pelvic pressure with a bearing-down feeling and sense of bulging in the vagina, together with the other symptoms of prolapse.

Operation. In most instances the repair can be carried out from the *vaginal side. The regular steps are carried out for exposure of a rectocele.* The two distinct bulges are identified, one lying on top of the other. The surgeon elevates the sac of the enterocele and gently dissects it free of the underlying rectum well up behind the cervix; with the sac dissected free the top is then excised and the peritoneal cavity entered. A purse-string suture is laid into the peritoneum around the neck of the sac, drawn tight, and tied. The redundancy is excised. To properly close the defect after excising the sac it is necessary to approximate the uterosacral ligaments together in the midline. They are brought into view by upward traction on the cervix. Two or three interrupted catgut sutures pass through both ligaments and include the top of the enterocele sac. These sutures are then tied there by approximating the uterosacral ligaments behind the cervix. The lone bulge of the rectocele remains. This is then repaired in the usual fashion.

If the surgeon feels that such a repair will not stand up over a long period of time he may elect to combine an abdominal attack with the pelvic repair. On exploring the pelvis the suture line will be found just below and between the attachment of the uterosacral ligaments to the posterior cervix or, if the uterus has been removed, in the region where the uterosacral ligaments should be—forward from the depths of the cul-de-sac. This area is closed in by using a continuous atraumatic No. 0 chromic catgut suture, starting in the region of the uterosacral ligament, carrying the suture back to the sigmoid, and from the sigmoid back again over the original suture line, bringing the peritoneum together and obliterating the entire cul-de-sac.

Occasionally when doing a total hysterectomy a very deep cul-de-sac will be noted and not infrequently a definite congenital hernia sac, which admits a finger into the opening between the two uterosacral ligaments. In such a situation the sac may be inverted and excised and the area between the two ligaments closed, followed by obliteration of the cul-de-sac. When no congenital hernia is present but the cul-de-sac is very deep, the bulging area between the ligaments can be closed by suturing the ligaments together in the midline, carrying the suture line down into the cul-de-sac and up on the sigmoid, being sure that bowel and peritoneum are so closed as to leave no bulge or opening and that no unobliterated areas are left behind. Then the stitch near the region of the sigmoid is carried back along the peritoneum to the original stitch behind the uterosacral ligament region and tied.

REPAIR OF VESICOVAGINAL FISTULA

Indication. Whereas in times past the most common cause of vesicovaginal fistulas was birth injury, by far the larger part as seen now are secondary to operative trauma incident to pelvic reconstruction or hyster-

ectomy, either by the vaginal or abdominal route. While the former group were troublesome because of actual loss of tissue the latter are technically difficult to repair because of their relation to the trigone and their rather inaccessible location. Many surgeons advocate various types of suture material, from the silver wire popularized by Sims to the stainless steel wire employed by Wayne Babcock. The routes of approach for operative repair are varied but resolve themselves down to: 1, the vaginal approach; 2, the suprapubic route, and 3, the transperitoneal attack. Combined procedures have their champions. It is the rare case today that requires other than the vaginal approach.

The problems confronting the surgeon are: 1, mobilization of the fistulous opening; 2, proper suturing, 3, exposure; 4, adequate mobilization of the bladder; and 5, proper postoperative drainage.

Operation. A midline incision beginning near the urinary meatus is carried downward to encircle the area of the fistula and continued beyond it, still in the midline. At this point, further exposure may be obtained by making a transverse incision in the vagina just above the cervix.

The dissection to expose the fascia should begin at a point relatively free of scar where the normal cleavage lines are not disturbed by previous operations or trauma; for that reason the area around the urethral meatus is the most logical choice. Clamps or tenacular forceps are placed on the cut vaginal edge and kept on tension, being held by the assistant. The operator applying traction on a flat plane on the bladder side begins to dissect to find the fascial planes in an obliquely posterior manner, as in the advancement operation. As the operator approaches the scarred area of the fistulous tract the cleavage planes are more obscure. Having found the proper fascial layer above, the problem is less complicated. The bladder should be freed up widely laterally to allow the fistula to come together without tension on the suture line. This is probably of more importance than the actual choice of suture material. If the cervix is present the bladder must be advanced upward off its surface.

1. Mobilization of the Fistulous Opening. With the bladder mobilized the fistula itself must be displaced down where it can be attacked. This may be done by introducing a straight male sound through the urethra or by passing a rubber catheter through the urethra and out through the fistula opening. The edges of the fistula are freshened with a sharp knife or scissor dissection.

2. Proper Suturing. By applying Allis forceps to the bladder following adequate mobilization it can now be determined whether the opening is to be closed in a longitudinal or a horizontal plane. The decision being made, the sutures—usually No. 0 chromic catgut—are then placed through all the muscular and fascial coats of the bladder, taking great care not to include the bladder *mucosa. To include the* bladder mucosa is to invite stone formation around the suture and certain failure The effect of the properly placed, interrupted catgut sutures may be used to overlie the first layer. If this is not possible because of scar fixation a modification of the split flap technic may be employed to serve as reinforcement. This is accomplished by putting the vaginal mucosa under tension and dissecting off the attached layer of fascia as a sheet. This layer is then sutured over

the primary suture line with interrupted catgut sutures, either directly or by overlapping. Silver or steel wire is used to close the vaginal mucosa.

3. Exposure. Inasmuch as many of the fistulas now encountered are secondary to a previously performed hysterectomy they are frequently small and invariably located in more or less scar tissue at the apex of the vagina. The classic Sims procedure may prove helpful, as may at times the extreme knee-chest position. Most operators now perform the operation in the lithotomy position but secure added exposure in the narrow vagina common to this type of case by employing some such procedure as the Schuchardt incision.

This incision is made on the left side by placing the labium on tension and dividing it at about the lower third, carrying it up along the lateral wall of the vagina as far as the fornix. On the skin surface the incision is carried down in a curving direction around the anus to terminate a short distance below the opening. The incision is then carried down to the levator ani muscles and out into the ischiorectal fossa, taking care not to damage the rectum. This step provides more complete exposure of the fistula situated high up at the apex of the vagina.

4. Mobilization of the Bladder. In most instances the normal landmarks, such as the cervix, will be absent. This important phase of the operation follows closely the technic described for the advancement of the bladder, except that extensive scarring exists either because of the fistula itself or as a result of previous attempt at repair plus the fact that the normal uterus and cervix are missing. The freed bladder muscle and mucous membrane are closed. The vaginal mucosa is then closed by interrupted sutures, taking great care to pick up the bladder fascia to one side and beyond the fistula, thus eliminating dead space. Silver wire, stainless steel, silkworm gut, or catgut may be used at the operator's choice.

5. Postoperative Drainage. A large part of the success or failure of this repair will depend upon the proper drainage of the bladder postoperatively. Some fistulas may be properly and satisfactorily handled by a Foley type catheter in the urethra, attached to an Alcock drainage circuit. For the most part, however, it is better to drain the bladder through a suprapubic cystotomy.

ABDOMINAL OPERATIONS

There are certain general principles bearing on the ease and safety of abdominal operations which should be discussed before going into detailed descriptions of the individual procedures Attention to these principles will minimize the likelihood of postoperative complications and will also make the actual performance of the surgery less troublesome.

Inasmuch as alterations in the electrolyte balance commonly occur in the postoperative period it is advisable where facilities are available to have a preoperative evaluation of such factors as blood sugar, chlorides, serum protein, nonprotein or blood urea nitrogen, and at times sodium and potassium. Blood electrolyte and fluid replacement have increased the scope of modern surgery to a large extent. In many instances administration

of blood or fluid may be necessary before surgery is undertaken. Unexpected hemorrhage may occur in the course of surgery. It is far better to be prepared to replace the blood than to have to meet the necessity as an emergency. In any poor risk patient an electrocardiograph study or roentgenogram of the chest may be most valuable in estimating the risk or in choosing the type of an anesthesia to be employed. A primary evaluation of the bladder and investigation of the urinary tract by either retrograde study or intravenous pyelogram is often indicated where surgery is to be done in the pelvis. Unsuspected pathology in areas of the abdominal cavity remote from the pelvis is not infrequently seen in operations performed for correction of genital difficulties. To encounter them without warning and without adequate preparation for dealing with them may lead to unfortunate consequences for the patient. The unexpected may appear even in the patient who has had a thorough preoperative work-up, but the aim should be to reduce to a minimum the element of chance. For example, the surgeon should consider the possibility in operating for any pelvic tumor that bowel may be adherent to the mass. In the dissection the bowel may be damaged either inadvertently or by necessity should the disease process involve the bowel. The introduction of a Miller-Abbot tube preoperatively may prove a lifesaving measure in such a situation. It is also useful in providing a wider operative field, as the small intestine threads on the tube. Less violent packing off of the bowel will be necessary, and pressure against the diaphragm will minimize the dangers of postoperative lung complications. Simple attention to details of this sort not only make for greater ease in performing abdominal surgery but materially decrease the risk to the patient.

Because the preoperative evaluation of the nature and extent of gynecologic conditions is often inaccurate it is important that a curettage precede every operation performed for pelvic cause. In this manner the surgeon is not so likely to be confronted with pathologic evidence of malignancy or even pregnancy in the specimen he has removed. In some instances a completely inadequate operation will have been performed for malignant disease or a totally unnecessary one for a pregnant uterus. In addition to the above a preliminary curettage and examination will make the surgeon recheck the observations made in the office examination without the benefit of the relaxation of anesthesia.

With the abdomen opened it is important that the remainder of the abdominal cavity be explored unless the surgery is being done as an emergency or for acute inflammatory conditions in the presence of pus. A systematic search according to plan should begin with the cecum, coming up along the ascending colon to the kidneys, liver, gallbladder, stomach, duodenum, transverse colon, spleen, kidney, and descending and sigmoid colon, as well as the small intestine and mesentery. Obvious disease in the ovary may be secondary to primary pathology in the colon. Abnormal findings should then be considered in relation to the relative importance. The planned surgical attack may require modification. Asymptomatic gallstones are often found. It would be foolhardy to attempt to combine cholecystectomy with pelvic surgery, but the knowledge of the presence of gallstones may prove valuable in the interpretation of right upper

quadrant or lower right chest symptoms in the recovery period. It is the obligation of the surgeon performing abdominal surgery to have some idea of what is going on in the abdomen over and above the local area on which he has planned his surgical attack, provided that in doing so he does not jeopardize his patient.

Before beginning the surgical attack on any pathologic process in the lower pelvis the surgeon should make every effort to provide himself with an adequate working field. To this end the uterus and adnexae should be mobilized and the intestine packed back out of the pelvis by gentle pressure with moist gauze. It is unwise to begin the surgical removal of any pelvic structure until this is done. Because of inflammatory disease, previous pelvic surgery, malignancy, or other cause, the intestine either small or large is not infrequently adherent to the uterus or adnexae. Such intestine must be freed before attempting to remove them.

The steps outlined above are common to all abdominal operations designed to deal with lesions in the pelvis. Careful attention to the details will materially aid the surgeon in bringing about a successful operation with a minimum of risk.

OPERATIONS ON THE ADNEXA

SALPINGECTOMY

Indication. The chief and practically only indication for removal of a Fallopian tube alone is found in ectopic pregnancy. Occasionally the tube may be found to be involved independent of the ovary in pelvic inflammation but the primary disease is one of involvement of the entire uterus and adnexa.

Operation. Where the operation is performed in the active bleeding phase of an ectopic pregnancy the primary step is to reach into the pelvis with the right hand and pull up on the uterus. This will in most instances control the most severe bleeding.

A clamp is applied to the round ligament of the uterus and upward traction applied. A clamp is applied to the fimbriated end of the tube. By lifting the tube gently upward the mesosalpinx with its vessel is visualized and clamps applied successively as the tissue included in each clamp is divided. The tube should be removed as far away from the ovary as possible to preserve the anastomotic blood supply of the ovary.

A mattress suture is applied at the cornua of the uterus, and a wedge-shaped section of the uterine wall, at the point of the tube attachment, is removed.

The entire area is then peritonealized by employing the peritoneal surface of the leaf of the broad ligament. This is done with a running fine atraumatic chromic catgut suture.

PLASTIC OPERATION ON THE OVARY FOR OVARIAN CYST

Indications. Too many ovaries are needlessly sacrificed for such benign conditions as simple follicle cyst, corpus luteum cyst, and endometriosis. Were the ovary of every woman an external appenda[illegible] the testes in

man, there would be fewer ovaries needlessly sacrificed. In the absence of malignant disease or the threat of malignant disease ovarian tissue should be conserved. Repeated pregnancies have followed the preservation of minimal amounts of ovarian tissue following conservative operation for endometriosis.

Operation. The ovary is grasped with Allis forceps at both the medial and lateral borders of the hilum and steadied by the left hand of the operator. With a sharp knife or with scissors the diseased portion of the ovary may readily be dissected out from the normal ovarian tissue. There is usually an excellent line of cleavage. This is as true for the so-called chocolate cyst of the ovary (endometriosis) as for the simple follicle cyst and the corpus luteum cyst, commonly mistaken for the chocolate cyst.

Very little bleeding is encountered and the cut edge of the ovarian tissue is readily reconstructed with interrupted or running atraumatic sutures.

SALPINGO-OOPHORECTOMY

Indications. For unilateral disease of the adnexa secondary to salpingitis, oophoritis, endometriosis, or ovarian cyst unilateral salpingo-oophorectomy is indicated. Where both adnexae need to be sacrificed the operation of choice is the removal of the entire uterus with adnexa, not bilateral salpingo-oophorectomy.

Operation. The most important step in the entire procedure is the freeing up of the diseased adnexa. It is important to recognize the fixation of endometriosis as against that of pelvic inflammation In the latter instance a line of cleavage can always be established between the inflammatory process involving the tube and ovary and the attached viscera, commonly the sigmoid. By placing a clamp on the tubal angle and ovarian ligament as the first step and applying traction the proper cleavage plane can more readily be determined. By and large with pelvic inflammation the freeing up should be done from below upward, chiefly by gentle finger manipulation, with only occasional help from a sharp instrument such as knife or scissors. A gentle pill-rolling manipulation of the tissue between the thumb and forefinger is a most useful maneuver. Where firm bands of tissue are encountered resistant to the above technic they should be avoided until they can be completely visualized before applying clamps. Such a finding usually indicates that a false cleavage plane has been found or vessels are present. Where the underlying pathology is that of endometriosis the maneuver noted above will not only fail but is dangerous because of the invasive nature of the disease. A most useful slogan of "stay on the uterine side" should be closely adhered to, for it is far better to leave the disease on the attached viscera than to remove a portion of the sigmoid or small bowel with the specimen The approach to this type of pathologic lesion is usually made from above downward and commonly with sharp instruments, such as knife or scissors.

The actual removal of the tube and ovary is uncomplicated. The first step, as previously noted, is the application of the clamp and the use of traction at all times. The adnexa should be thoroughly freed from attached

viscera and posterior leaf of the broad ligament before initiating the first maneuver for their removal.

To secure adequate exposure of the infundibulopelvic ligament a clamp is placed on the freed end of the tube and drawn to the midline toward the uterus. With the uterus on traction in a direction away from the ligament to be exposed, excellent visualization of the vessels in the ligament is obtained. A smooth curved needle with No. 1 catgut is then placed in an area free of vessels and tied around the ovarian vessels. This suture is followed by another placed about one-quarter inch medial to the initial stitch. A curved clamp to prevent back bleeding is then placed paralleling the direction of the tube. It will be noted that the sutures are placed and tied before the clamp is applied. The ovarian vessels are then divided along the line of the clamp. This incision may safely be carried to within about three quarters of an inch from the uterine wall where the ovarian branches of the uterine vessel are encountered. By keeping the uterus on traction and applying countertraction on the adnexa the vessels are readily visualized. A clamp is then placed across these vessels and the tissue above the clamp divided.

The adnexa now hang free from the attachment of the tube to the cornua of the uterus. A mattress suture of No. 1 catgut on a smooth needle is then placed deep into the muscle of the uterus at the cornua and a wedge-shaped removal of the tube performed. The deep mattress suture is designed to catch a small vessel which is always encountered in this area and is now tied. The tube is excised from the cornua of the uterus, care being taken not to cut the suture placed there. After the tube has been removed the stitch is tied and the area of excision of the tube is closed with separate interrupted sutures.

The entire cut edge of the broad ligament and the stump of the ovarian vessels are now peritonealized with a running atraumatic suture.

Loss of support from the ovarian vessels on one side of the uterus makes it well to complete the operation with a suspension of the uterus.

When the operation has been performed for an ovarian cyst or tumor the specimen should be opened on an adjoining sterile table to determine the presence or absence of the gross characteristics of malignant disease, such as papillary projections. If in doubt frozen section should be done. The finding of malignancy indicates a total hysterectomy with removal of the opposite adnexus. It is better to discover the malignancy while the abdomen is still open rather than days later with the operation imperfectly completed and a potential source of residual or recurrent disease still present.

UTERINE SUSPENSION

Indications. Where acquired or congenital retroversion is of such magnitude that the fundus of the uterus remains in malposition despite attempt to replace it by manual manipulation, application of pessaries, or by exercises, some type of intra-abdominal suspension may be indicated. Perhaps one of the best indications is in the problem of sterility of long standing where the cervix points either in the axis of the vagina or toward the anterior vaginal wall. Replacement of the uterus will tend to force the cervix toward the pool of semen in the posterior fornix. In the course of

conservative operations for endometriosis extensive operative denudation may occur which together with the retroversion commonly associated with the disease, particularly if it involves the uterosacral ligaments and sigmoid, may be a twofold reason for performing a Baldy-Webster type of suspension, both to correct the retroversion and to provide adequate peritonealization.

Whenever an adnexus has been sacrificed it is a wise procedure to suspend the uterus.

Backache and dysmenorrhea may be an indication for suspension of the uterus if all other possibilities have been explored and judged innocent.

TYPES OF OPERATION

The Olshausen Operation. A double heavy braided silk or double chromic No. 1 catgut suture on a cutting needle is placed beneath the round ligament which has been put on stretch by traction on the tenaculum on the fundus of the uterus. This suture is placed at a point approximately one-half inch from the insertion of the round ligament on the uterine wall.

Clamps are then placed on the right peritoneal edge of the abdominal incision, putting it on tension. The same thing is also done to the fascia overlying the rectus muscle. At this point it is well to determine the anatomic position of the deep epigastric vessels by palpating through the rectus sheath while the fascia and peritoneum are on tension.

The position of these vessels once determined, the cutting needle with heavily braided silk is passed through peritoneum, rectus muscle, and fascia to emerge on the superior surface. It then returns to the abdominal cavity through the above sutures in reverse order.

The maneuver is repeated on the left side passing beneath the left round ligament. The sutures are then tied within the peritoneal cavity, bringing the uterus by means of the round ligament against the anterior abdominal wall.

Disadvantages. Proper placement of the sutures beneath the round ligament is essential lest a loophole be left through which small bowel may herniate and become strangulated. Because of this possibility the operation is gradually being supplanted by suspension operations of the Coffey or Baldy-Webster type.

Advantages. The Olshausen operation is easily performed, and subsequent pregnancies present few complications. The uterus retains its new position tolerably well after repeated pregnancies.

The Baldy-Webster Operation. The mechanical principle involved is one of shortening the round ligaments. The uterus is placed on forward traction to expose the posterior leaf of the broad ligament. The peritoneum is then picked up and incised in a bloodless area beneath the ovarian ligament. A loop of the round ligament is drawn through the opening and sutured with interrupted catgut sutures to the posterior wall of the uterus in the midline just above the level of the internal os. The same procedure is carried out on the opposite side.

The defect in the peritoneum of the posterior leaf must be closed to prevent any opening into which small intestine may herniate. The peri-

toneum is tacked over the round ligaments to the posterior uterine wall burying them beneath a peritoneal cover.

ADVANTAGES. This is a satisfactory suspension for subsequent pregnancy. Its chief place is in conjunction with a conservative operation for endometriosis or pelvic inflammation where denuded areas of peritoneum result. The raw areas are easily covered while providing satisfactory uterine suspension.

MARSHALL-MARCHETTI PROCEDURE

Stress incontinence is a common and distressing problem for many older women. Many operations have been described for correction of the sagging neck of the bladder which appears to be the constant anatomic finding in these cases. In the majority of instances a satisfactory Kennedy type of repair (see page 843 for technic) will prove adequate. The Marshall-Marchetti type of reconstruction has a useful place where there has either been a failure of the Kennedy operation or where stress incontinence is present in a woman who must have a total removal of the uterus. In the latter situation hysterectomy will almost invariably increase the degree of incontinence. It becomes a very simple matter to add the steps of the Marshall-Marchetti procedure to those of total hysterectomy. The operation may then be performed as the sole maneuver in conjunction with hysterectomy.

Operation. Either a new paramedian incision is made or the exposure of the prevesical space is provided through the same incision employed for entering the abdomen. It is not necessary to enter the abdominal cavity unless the operation is being performed in conjunction with a hysterectomy or other intra-abdominal procedure.

The fascia is divided and the recti muscles exposed. Retractors are placed in the lower end of the wound beneath the muscles thereby exposing the peritoneum and overlying transversalis fascia. The peritoneum is then gently separated from the under surface of the muscle. The surgeon then places the flat of the hand on the peritoneal surface. By gently depressing the palm of the hand and flexing the fingers the prevesical space is bloodlessly exposed. The bladder is retracted upward in this maneuver until the neck of the bladder and the urethra come into view.

An inlying catheter of the Foley type has previously been placed in the bladder. The reparative sutures will be placed more easily if an assistant is employed to introduce a hand into the vagina. By placing the Foley catheter on traction and pushing up on either side of it at the bladder neck the paraurethral tissue becomes readily apparent to the surgeon. A series of interrupted sutures are placed in the paraurethral tissue and periosteum of the under surface of the symphysis beginning well down on the urethra away from the bladder neck. Successively placed sutures on either side approach the neck of the bladder. Several sutures on either side are placed before they are tied and divided. One or two sutures are similarly placed in the bladder wall taking care not to penetrate into the bladder interior. The sutures should be of catgut rather than silk. A drain should be placed in the prevesical space and left there for 48 hours. The inlying catheter remains in position.

Advantage and Disadvantage. There are many operations designed to correct stress incontinence. The Marshall-Marchetti procedure appears to be easily preferred and provides satisfactory results. The disadvantage lies in the danger of creating an osteitis or a septic osteochondritis through excessive trauma to the periosteum of the symphysis.

PRESACRAL NEURECTOMY

Indications. Presacral neurectomy should not be offered indiscreetly for the relief of dysmenorrhea. All other forms of therapy should be tried before advocating excision of the presacral nerve plexus. Presacral neurectomy will be permanently effective in the properly selected case if the pain is incapacitating and confined to the uterus itself, and if a complete operation is performed. It will not relieve backache, and no effect should be anticipated on pain of adnexal origin.

A screening test is available for aid in the selection of suitable candidates for presacral neurectomy. Estrin therapy given early in the menstrual cycle will relieve pain provided ovulation is suppressed. If the pain is not relieved and we can be sure ovulation has not taken place then the patient either has unrecognized pelvic disease or is truly a candidate for psychotherapy, not surgery. As long as the estrin test has proven to be effective one may anticipate relief from presacral neurectomy approaching 100 per cent.

The failures following this operation can be traced for the most part to improperly selected cases or an incomplete operation. The rare case may show nerve regeneration.

The operation is preferred primarily for essential dysmenorrhea but may be used in conjunction with conservative operations for endometriosis.

Operation. The ramifications of the sympathetic nerve supply in the pelvis are widespread and all branches of the presacral nerve plexus must be removed. The conception of the presacral nerve as a single trunk is erroneous. It will not suffice to merely remove a segment of nerve at the bifurcation of the iliac vessels.

The dissection should remove all the nerve pathways from the bifurcation of the aorta to and including the inferior mesenteric ganglia along the sides of the rectum deep in the pelvis, well below the promontory of the sacrum. The field must be kept scrupulously dry. The danger lies in possible damage to the midsacral veins which empty into the left common iliac vein. The dissection must be carried laterally along the common iliac vessels continuing down along the internal iliac vessels. Fibrous bands containing nerve fibers adhere to the under surface of the peritoneum and must be stripped clean after identifying the ureters on both sides to prevent injury to them.

After the ramifications are mobilized the nerve is elevated by forceps and gently dissected free from the superior surface of the left common iliac vein which crosses the operative field transversely above the promontory. The entire nerve is now mobilized toward the midline. The nerve mass is divided between clamps The distal end of the bundle is tied toward the symphysis and the nerve is dissected free from the anterior surface of the

sacrum. It is here that the midsacral veins may be damaged. When completely mobilized the lateral excisions of the bundle are clamped and ligated and the entire distal segment of nerve is removed. The upper nerve segment is then elevated and dissected off the bifurcation of the aorta. It is then clamped, divided, and tied.

To do less than this amount of surgery is to run the risk of failure. Morbidity is present only when the ureter is damaged or retroperitoneal hematoma appears.

HYSTERECTOMY

The indications for hysterectomy are numerous. The most common are fibroids, abnormal uterine bleeding in the menopause group, prolapse, "fibrosis uteri," and as a necessary part of an operation for certain diseases of the adnexa. It is always unwise to leave a uterus in place when both tubes and ovaries have been removed. Usually in pelvic inflammatory disease a total hysterectomy is performed if it has been necessary to sacrifice both tubes. The unused uterus is not necessary to health, and the attempt to conserve menstruation if childbearing is not possible is to be condemned. The ovaries will function perfectly well if the uterus has been removed.

Types of Hysterectomy. There are four basic operations for the removal of the uterus: 1, vaginal hysterectomy; 2, supravaginal hysterectomy; 3, total hysterectomy; and 4, radical hysterectomy (Wertheim operation). The first three are in common usage, while the fourth has again come into prominence in connection with the newer concept of the management of carcinoma of the cervix. The choice of operation is modified by such factors as the type of pathologic lesion presented, general condition of the patient, history of previous surgical attempts in the same operative area, and by the judgment and skill of the surgeon.

Terms. In common usage there appears some confusion in employing the term "total" hysterectomy. The term "total" refers to the removal of the entire uterus, including the cervix, with or without the adnexa. It does not mean supravaginal hysterectomy including both tubes and ovaries, as is frequently suggested. The term "pan" hysterectomy means the removal of all the uterus, or the same as total hysterectomy. It has nothing to do with the adnexa.

1. VAGINAL HYSTERECTOMY

See pages 848-854.

2. SUPRAVAGINAL HYSTERECTOMY

Indications. By and large supravaginal hysterectomy is performed for benign uterine conditions such as fibromyomata, pelvic inflammation, and endometriosis. Formerly this operation was combined with a repair of the cervix and pelvic floor. Where the cervix is in need of repair the operation of choice is a total hysterectomy rather than a supravaginal.

This operation is the most widely employed type with the lowest mortality in the hands of the average surgeon. Where the technical difficulties are great, as found in certain cases with extensive pathologic lesions associated *with pelvic inflammation or endometriosis,* it may well

be the safest procedure. However, there still remain an increasing number of carcinomas of the cervical stump arising some years after a supravaginal hysterectomy.

Contraindications. Supravaginal hysterectomy is definitely contraindicated in such conditions as carcinoma of the body of the uterus or in carcinoma of the ovary. The first may be ruled out by a preliminary curettage as the first step in the operation. If doubt still exists a total hysterectomy should be done. The second may be determined by having the ovarian tumor sectioned by a pathologist or the surgeon himself on a separate sterile table before continuing with the operation. For either type of cancer total hysterectomy is the operation of choice. If there is any doubt the latter procedure is indicated.

Technic. PRELIMINARY PREPARATION. Whether or not the patient has voided preliminary to the operation it is well to have the patient catheterized. A distended bladder may add enormously to the technical difficulties of the operation. A preliminary vaginal *inspection* and *curettage* are indicated whenever supravaginal hysterectomy is contemplated independent of the question of other surgical procedures in the vaginal area.

ABDOMINAL OPERATION. The abdomen is opened through whatever type of incision the surgeon elects to employ. The edges of the incision are properly protected with towels or sponges. To obtain a satisfactory exposure of the operative field the patient is placed in the Trendelenburg position and the intestine gently packed out of the pelvis with moist gauze.

The pelvis is then revealed for inspection. Should the uterus and its adnexae be fixed in the pelvis by inflammatory disease *they must first be mobilized.* After the bowel adhering to the uterus is freed, the separation of the adnexae should be begun from below upward, employing the gloved hand, by rolling the tissue between the thumb and forefinger after first gently determining the proper line of cleavage. This must be done gently. Where the tissues do not separate readily they should be brought under direct vision, for this indicates that pathologic invasion of important structures, such as the rectum, has occurred. This is particularly true of *endometriosis* which by its nature is invasive in character.

After or before freeing up the uterus a tenaculum is firmly placed in the fundus of the uterus and traction is then maintained throughout the operation to the time of actual removal. An important step now follows. The uterus is drawn up and back to expose the anterior leaf of the peritoneal reflection from the bladder which is opened on either side of the median raphe. By introducing the finger in the space the areola tissue around the bladder is separated without bleeding, giving excellent exposure of the uterine vessels as they lie on the posterior surface of the broad ligament. These two incisions are then connected, care being taken as the incision crosses the midline that the fundus of the bladder is not damaged. By placing clamps on the peritoneal reflection it is now possible to free up the bladder from the anterior reflection for a short distance Later in the operation this step permits a peritoneal closure over the cut cervical stump without pulling the bladder over it. Postoperative bladder complications are thereby reduced. The *technical advantages of performing this maneuver as the preliminary step are considerable.*

The operator is next faced with the decision of whether or not to remove the adnexae as a whole or in part. For purposes of demonstration the description will follow a complete removal on the right side and conservation on the left.

The tube on the right side is grasped with the forceps to expose the ovarian vessels running in the infundibulopelvic ligament. Two sutures are then placed in the bloodless area below the ligament about one-half inch apart. A Kelly clamp is then placed on the uterine side including the ovarian ligament down to and including the round ligament. The infundibulopelvic ligament is divided between the distal suture and the clamp. A suture is then placed around the round ligament and placed on traction by leaving the suture long and clamping the distal end of the suture. By keeping the uterus and round ligament on tension it is possible to visualize the proper area for division of the posterior leaf of the broad ligament. It is important to cut the broad ligament along the under surface of the round ligament to avoid blood vessels. It will be observed that the ovarian and round ligaments are separately ligated.

The left adnexa are to be preserved. Again two sutures are placed one-half inch apart but in this instance they include the ovarian ligament adjacent to the uterus and the proximal tube and not the infundibulopelvic ligament. After placing and tying the sutures the back clamp is applied and the ovarian ligament and tube are divided. The procedure for the round ligament duplicates that performed on the right side.

The uterine vessels are next clamped and tied. At this point it is well to determine the relation of the bladder to the cervix. This is done by grasping the cervix with the right hand between the thumb and fingers. The uterine vessels as the result of the initial operative step should be readily visualized and must be identified for it is at this point that the ureter may be either sectioned or included in the uterine stitch.

Beginning on the right side a clamp is placed on the right uterine artery at right angles to the cervix. The placing of this clamp is greatly facilitated by the constant traction on the uterus which prevents the parametrium being thrown into folds and lessens the chance of enclosing any more than the uterine artery in the clamp. A back clamp is then so placed on the uterine side as to leave a wide cuff The assistant with the curved clamp in hand awaits the section of the uterine artery along the edge of the clamp placed on the uterine side, and secures the uterine artery again as it presents in the cuff held by the first clamp. A chromic catgut No. 0 suture is then placed behind the initial clamp and ligated leaving the safety clamp in place. This clamp is then ligated with a similar stitch ligature. The same procedure is then carried out on the left Both the ovarian and uterine vessels have now been doubly sutured

The uterus is then drawn forward, the posterior cervical peritoneal covering is transversely incised and dissected off the cervix to provide a minimal peritoneal cuff. The uterus is drawn backward to expose the anterior uterine mass at the cervix The uterus is then amputated by coning out the cervix. A clamp for traction should be immediately placed on the anterior lip of the cervix by the assistant. In this manner troublesome bleeding from the cervical stump may be visualized and controlled.

The cervical stump is then closed with deep, interrupted sutures. The round ligaments are then sutured to the cervical stump. Inasmuch as the round and ovarian ligaments were not included in the same suture the ovary lies easily without placing tension on the ovarian vessel; thus tension on the ovarian vessels and possible cystic degeneration of the retained ovary due to impaired blood supply may be minimized.

The peritoneal flap previously developed is now used to completely peritonealize the pelvic floor by suturing the raw edges of the broad ligament and cervix.

3. TOTAL HYSTERECTOMY

Indications. In the past total hysterectomy with removal of both adnexa was performed for malignant disease of the fundus of the uterus or ovaries. It has been inadvisedly used for carcinoma of the cervix. In the recent literature total hysterectomy with or without the removal of the ovaries is being increasingly advanced as the operation of choice whenever abdominal hysterectomy is indicated. This stems from the frequent finding of carcinoma of the cervical stump following supravaginal hysterectomy, as well as the unsatisfactory results from repair of the lacerated cervix. In actual practice the mortality and morbidity following total hysterectomy should be no greater than for supravaginal hysterectomy, provided it is not employed in the advanced pathologic states of pelvic inflammation or endometriosis, unless in expert hands.

Total hysterectomy may be employed for moderate degrees of prolapse with very satisfactory results. The more advanced cases of prolapse of the uterus associated with a large cystocele and rectocele are best attacked by the vaginal route.

Contraindications. For the casual operation where the uterus is fixed in the pelvis because of pelvic inflammation or endometriosis, or where a grossly hypertrophied cervix is present, it will probably be well to perform a supravaginal hysterectomy. It is nevertheless incumbent upon the surgeon to familiarize himself with the technic of total hysterectomy.

Technic. Preliminary Preparation. Inasmuch as the vaginal outlet will communicate with the abdominal cavity careful preparation of the vagina with double strength Schiller's solution * is an essential. Likewise, it will be necessary in the course of the operation to mobilize the bladder to a greater extent than is necessary in the technic for supravaginal hysterectomy. It is therefore increasingly important to catheterize the bladder irrespective of whether the patient has previously voided.

The patient should have a curettage as a preliminary step to the removal of the uterus for the reasons previously outlined. The most important reason is the finding of unsuspected carcinoma by the pathologist after the operation has been completed. If the unexpected cancer is of the endometrium the ovaries may have been left in situ or if of the cervix a totally inadequate operation has been done. In either case the situation is an unhappy one which might have been avoided by employing the universal rule of performing a curettage when any pelvic laparotomy is to be done. Since curettage may not be 100 per cent accurate it is a good idea to supple-

* Made up of iodine, 2 parts, potassium iodide, 4 parts, distilled water, 300 parts.

ment this move by insisting that every uterus should be opened at the operating table before closing the abdomen. It will not help much if the cancer is primary in the cervix but it will be useful in deciding whether the ovaries should be removed if carcinoma is discovered in the endometrium. The safest procedure is to adopt a routine of doing both the curettage as a preliminary step and sectioning the uterus for further confirmation before completing the operation.

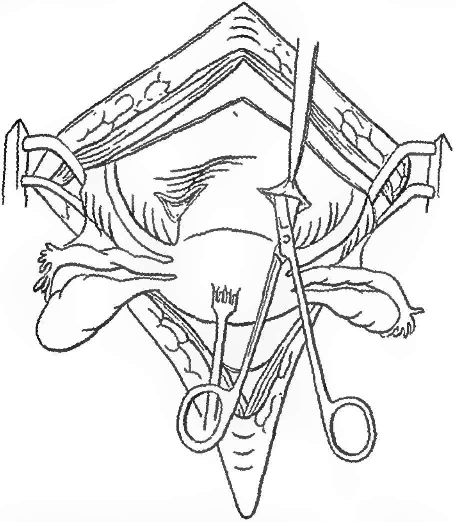

Fig. 20-42. This represents the most important step in the operation. The uterus is on traction exposing the anterior cervical wall and the bladder. The anterior leaf of the broad ligament is picked up and the peritoneal surface incised on both sides.

Abdominal Operation. The preliminary steps of mobilization of the uterus, packing the intestines out of the pelvis, and Trendelenburg position do not vary from the details of the supravaginal hysterectomy. *The tenaculum should not be applied on the fundus of the uterus if malignant disease has been either proved or is suspected.* Traction on the uterus is maintained by a Kelly clamp placed close to the uterus on the broad ligament. Again, continued traction is of paramount importance.

The first maneuver involves incision of the anterior leaf of the broad ligament of peritoneal bladder reflection lateral to the cervix on both sides (Fig. 20-42). Kelly clamps are placed on the cut edge of the peritoneum and held taut to permit gentle blunt dissection of the broad ligament with the gloved finger or blunt-end scissors (Fig. 20-43). The lateral areola

Fig. 20-43. By placing the edge on traction with Kelly forceps not shown on the left side of the drawing, the areola tissue lying alongside the cervix may be pushed downward freeing up the bladder laterally and exposing the vessels and ureter without trauma.

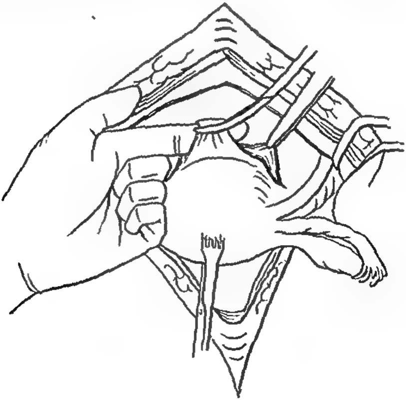

Fig 20-44 The connecting peritoneal bridge is connected. The bladder is then gently pushed distally off the cervix

attachments are separated to more completely mobilize the bladder. The bladder is then easily pushed distally with wet gauze (Fig. 20-44), the ureters tending to descend out of the field with the bladder as it is advanced downward. This move provides a complete view of the anatomy of the lower broad ligament including the division of the uterine artery into the cervical and body branches as well as the relation of the ureter to them. By freeing up the bladder laterally in the broad ligament a wider quadrilateral field of operation is provided rather than a narrow conelike area.

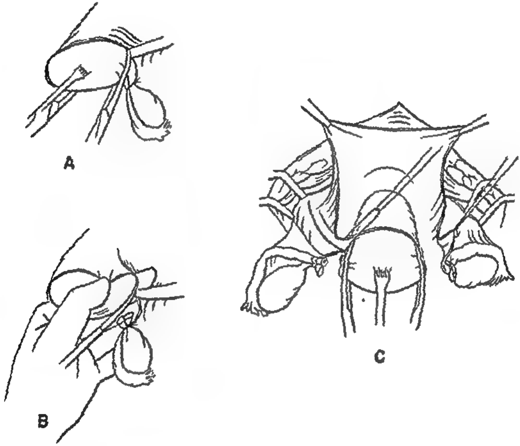

Fig 20-45 The attack is then begun on the adnexa A, the uterus is on traction A single stitch ligature has been [illegible] a Kelly clamp applied [illegible] divided between clamp [illegible] ment is shown doubly lig[illegible] outside the abdomen to [illegible] back bleeding. By placing the round ligament and uterus on tension the posterior leaf of the broad ligament is seen and excised under direct vision It is shown excised on the right.

The next step involves the ligature of the right ovarian vessels accomplished by passing a curved needle with No. 1 catgut below the vessel in the infundibulopelvic ligament under direct vision, the surgeon pulling the uterus to the left while the assistant holds the adnexa out of the field (Fig. 20-45). This is followed by a second suture placed one-half inch from the first suture. The last suture is held while a hemostatic clamp for back bleeding is placed on the uterine side on the broad ligament, including the round ligament. An incision is then made along this clamp leaving the two sutures on the ovarian vessels. A separate suture is passed around the round ligament. By putting traction on the uterus while the assistant holds

the long suture on the round ligament it is now possible to split the posterior sheaf of the broad ligament with the opened scissor blades under direct vision and without bleeding. This incision should follow the undersurface of the round ligament to avoid bleeding. Thus the entire broad ligament is widely and bloodlessly exposed. The same procedure is now carried out on the left or operator's side.

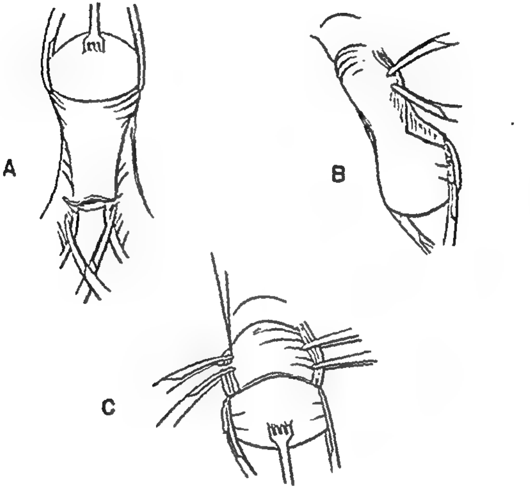

Fig. 20-46. A, the uterus is then drawn toward the symphysis to expose the uterosacral ligaments which are divided between clamps, thus aiding in mobilizing the uterus. A transverse incision is then made in the peritoneal covering. B, the uterine vessels are clamped in such a position as to leave a cuff above the distal clamp. C, the vessels are then divided along the proximal clamp as the assistant applies another clamp to the cuff left by the previous step. On the left a stitch ligature has been placed around the uterine vessels on the left with the safety clamp in place. These vessels are doubly ligated.

Before attacking the uterine vessels greater mobilization of the uterus is obtained by dividing the uterosacral ligaments (Fig. 20-46). The operator, by applying traction on the clamps or tenaculum holding the fundus in the direction of the bladder, brings the uterosacral ligaments into view. Each is separately ligated with a curved needle suture placed superficially but around the ligament, for each contains a vessel. It is often easier to clamp the uterosacral ligaments with Kelly hemostats and leave them in the pelvis, placing mattress sutures about the latter when attaching them to the corners of the vagina. To include too much tissue here is to run the risk of including the ureter.

The peritoneal reflection may be transversely incised above the cut ends of the uterosacral attachments and the ligaments and peritoneum gently dissected back off the posterior wall of the cervix. This maneuver is of particular value when, as in endometriosis, the sigmoid is attached to the uterus as so frequently happens at this point. This can often be done gently with the gloved finger once the line of cleavage is apparent as part of the maneuver to palpate the remaining anatomic landmarks between the thumb and the anterior wall of the cervix and the hand behind the cervix, which should always be done at this stage. It is often not necessary to do more than clamp the uterosacral ligaments and free them from the area behind the cervix. The bladder reflection, length of the remaining cervix, and position of the uterine vessels with their relation to the ureter may all be determined by this step.

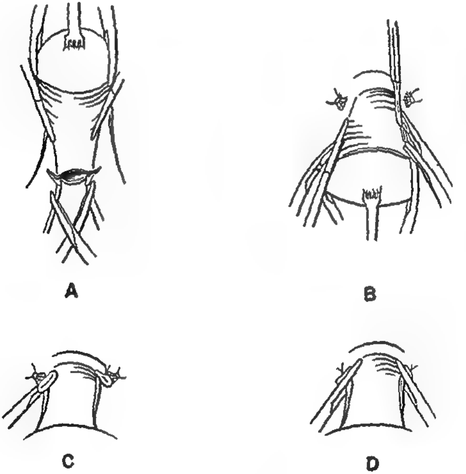

Fig 20-47. A, the uterosacral ligaments have been divided B, clamps are placed along the side of the cervix medial to the ligated uterine vessels C, the cervical branches of the uterine vessels are included in the tissue excised in the clamp D, the area in the above clamp has been ligated by stitch ligature and the step repeated

The uterine vessels are now identified and the relation to the ureter established, if possible. By the preliminary step of advancing the bladder much of the danger of damaging the ureter has been minimized. Inasmuch as the entire uterus, including the cervix, is to be removed the uterine vessels must be clamped a slight distance from the cervix (Fig. 20-47). The ease of accomplishing this is facilitated by upward traction on the uterus

in the opposite direction from the side of the broad ligament being approached. The clamp is applied *at right angles to the cervix* and again a back clamp is placed along the uterine side, leaving a one-quarter inch cuff between the clamps. The division of the vessel is then made along the uterine clamp while the assistant clamps the cut end of the vessel presenting in the cuff. Keeping traction on the uterus, the uterine vessels are doubly ligated. The same procedure is performed on the opposite side.

At this point the layer of pubocervical fascia overlying the cervix becomes evident and may be incised transversely. This minimizes the dangers of applying the straight Kocher clamps along the side of the cervix. It is at this point that the ureter may be injured by clamps or ligated by suture. If the straight Kocher clamp is applied along the cervix and the tip can be seen to have the layer of fascia on the lateral or ureteral side, division of the ureter is not possible. This clamp is placed to control the cervical branch of the uterine artery. The full extent of the bite should be under direct vision. No back clamp is needed. The incision is now made along the Kocher clamp, leaving enough edge of tissue so that it does not retract out of the clamp. This is a very poor area in which to blindly apply clamps following such an accident. A curved suture is now placed behind the Kocher clamp and tied. The same procedure is followed on the opposite side.

An alteration to the lifting of the fascia from the cervix and applying the Kocher clamps under the fascia is to place the straight Kocher clamp inside the ties of the uterine arteries and, pointing the clamps inward to the vagina, to cut along the inside of the clamps, leaving a fair amount of tissue in the clamps to prevent the fascia from slipping out. If this step is done as described, no injury to the ureter will take place as it is definitely lateral to the clamps. The ureter can be easily palpated along the lateral pelvic wall between the thumb and forefinger as it crosses under the uterine branch of the internal iliac artery. It can be followed easily to the uterine artery ureteral junction and avoided.

The need for more clamps on the fascia about the cervix depends on the length of the cervix which can again be evaluated by palpation.

The vaginal reflection now comes into view and a curved Kocher clamp is placed on each lateral corner where the blood supply of the vaginal cuff is most often encountered (Fig. 20-48). The position of the bladder relative to the anterior vaginal wall below and the cervix above is now checked by palpatior [illegible]
a dry ha [illegible]
The vagina is now opened by incision over each curved Kocher clamp, leaving sufficient tissue so that the tissue will not slip out of the clamps. By continuing traction the vaginal mucosa is visualized and the entire uterus is removed as the vaginal wall is incised. Some free bleeding may be encountered from the cut edge of the vagina. The corners of the vagina are sutured by a mattress suture, and the ends of the suture left long and clamped to hold the vagina up out of the pelvis. To further control bleeding a running or a locked suture is placed around the severed vaginal edge. It is important to secure the vaginal mucosa and vaginal fascia or smooth muscle together to prevent postoperative bleeding. In this technic the

vagina is left open beneath a peritonealized floor. This provides the only drainage employed. Many surgeons close the vagina by suturing the anterior and posterior layers together with interrupted sutures.

At this point the uterus should be presented to the pathologist if one is available; if not, the anesthetist or other available medical personnel should be asked to incise the uterus to expose the endometrial cavity. The surgeon should then inspect the specimen which has been opened for possible gross malignant change. If there are no suspicious areas he may then proceed with the reconstruction of the pelvic floor.

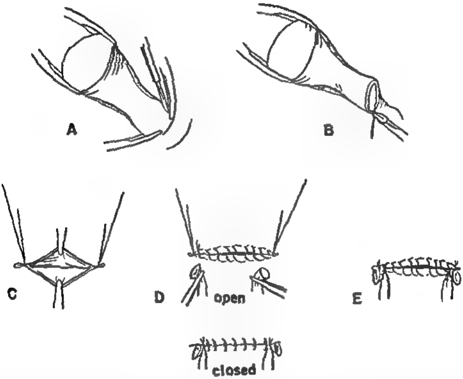

Fig 20-48 A, the vaginal fornix has now been reached and bilateral clamps placed. B, the vagina has been opened and the clamp on the right angle included in a stitch ligature. C, the cut edges of the vaginal mucosa are held apart A stitch ligature is in place at both lateral angles D, a running suture includes the cut vaginal edge. The uterosacral ligaments with the clamps are approximated to the posterior vaginal wall The illustration below shows the vagina exposed with interrupted sutures. Both methods are used. E, the uterosacral ligaments are sutured to the posterior vaginal wall.

The uterosacral ligaments are resutured to the posterior vaginal wall to hold the vagina back in the pelvis where it belongs, and the round ligaments are sutured to corners of the vagina to hold it up (Fig. 20-49). By this reconstruction the vaginal walls are not allowed to contract at the apex the foreshortening of the vagina is avoided.

The entire area is now peritonealized by suturing the leaves of the broad ligament together and continuing to the bladder flap peritoneum which is sutured to the posterior wall of the vagina.

The appendix, if present, may either be removed at this stage or as the first step in the operation. The wound is closed without drainage. An inlying catheter of the Foley type is placed in the bladder if a perineorrhaphy is done following the total hysterectomy. If a patient has had children, care should be taken to repair the relaxed perineum which is so

often present. The patient is placed in the lithotomy position for this maneuver after the abdomen has been closed. If the operation has been time-consuming or the patient is in poor general condition following the abdominal procedure perineal repair may be postponed, but it almost invariably should be done at some stage.

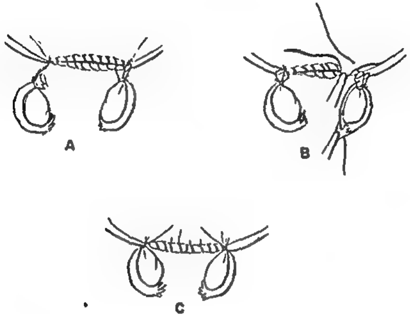

Fig 20-49. A, the ligated round ligaments are sutured to the closed vaginal cuff. The ovarian pedicle may be seen lying free without tension B, the cut edge of the anterior peritoneal edge is being used to peritonealize the raw area. C, the completely reconstructed floor is now peritonealized.

4. RADICAL HYSTERECTOMY FOR CANCER OF THE CERVIX WITH BILATERAL PELVIC LYMPH NODE DISSECTION

This operation, although popularly called the Wertheim operation, is considered to be far more radical, and should be called radical hysterectomy for cancer of the cervix with bilateral pelvic lymph node dissection.

Indication. The accepted treatment for cancer of the cervix is either a combination of x-ray and radium treatment or radium treatment alone. Despite the fact that the disease is clinically confined to the cervix in about 25 per cent of the total number of cases a certain percentage of this group (20 per cent) will die of their disease before five years have elapsed. The patient's tumor may be either radiation-resistant or the clinical evaluation of the extent of the disease has been incorrect. Extension of the cancer may already have advanced to the iliac or obturator nodes yet evade detection by the examining finger.

Where the disease remains confined to the cervix, as in the Stage I of the International Classification, or there exists but minimal extension in the direction of the vaginal fornix the surgeon may elect, if he is technically qualified and the patient is a good operative risk, to perform a radical Wertheim procedure combined with a dissection of the complete pelvic lymph node chain. It is not an operation to be performed by the occasional surgeon or one not completely familiar with the technical details of the operation and its many vicissitudes

vagina is left open beneath a peritonealized floor. This provides the only drainage employed. Many surgeons close the vagina by suturing the anterior and posterior layers together with interrupted sutures.

At this point the uterus should be presented to the pathologist if one is available; if not, the anesthetist or other available medical personnel should be asked to incise the uterus to expose the endometrial cavity. The surgeon should then inspect the specimen which has been opened for possible gross malignant change. If there are no suspicious areas he may then proceed with the reconstruction of the pelvic floor.

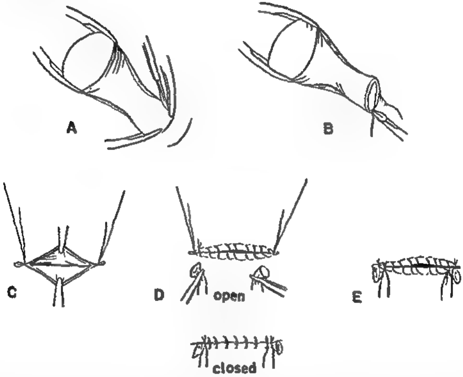

Fig 20-48 A, the vaginal fornix has now been reached and bilateral clamps placed B, the vagina has been opened and the clamp on the right angle included in a stitch ligature. C, the cut edges of the vaginal mucosa are held apart. A stitch ligature is in place at both lateral angles D, a running suture includes the cut vaginal edge. The uterosacral ligaments with the clamps are approximated to the posterior vaginal wall. The illustration below shows the vagina exposed with interrupted sutures. Both methods are used E, the uterosacral ligaments are sutured to the posterior vaginal wall.

The uterosacral ligaments are resutured to the posterior vaginal wall to hold the vagina back in the pelvis where it belongs, and the round ligaments are sutured to corners of the vagina to hold it up (Fig. 20-49). By this reconstruction the vaginal walls are not allowed to contract at the apex the foreshortening of the vagina is avoided.

The entire area is now peritonealized by suturing the leaves of the broad ligament together and continuing to the bladder flap peritoneum which is sutured to the posterior wall of the vagina.

The appendix, if present, may either be removed at this stage or as the first step in the operation. The wound is closed without drainage. An inlying catheter of the Foley type is placed in the bladder if a perineorrhaphy is done following the total hysterectomy. If a patient has had children, care should be taken to repair the relaxed perineum which is so

the infundibulopelvic ligament. The infundibulopelvic ligament is tied about 1½ inches from the clamp previously placed on the uterus. The stump is grasped and the ligament is tied again with a repeated stitch ligature, leaving two ties on the ovarian vessels in the infundibulopelvic ligament. The ligature of the last tie is left long and grasped at the distal end by a clamp. The round ligament is then tied with a stitch ligature and cut. These clamped ties on the infundibulopelvic and round ligaments are allowed to lie over the lateral edges of the incision thus helping to place the lateral peritoneum on tension. The same procedure is then carried out on the left hand side. Both tubes and ovaries are removed along with the uterus.

The uterus is now pulled to the left and up and the dissection commences. The peritoneum over the common iliac artery just below the bifurcation of the aorta is picked up with forceps and the peritoneum incised. With the scissors in this opening a line of cleavage can be easily found and the peritoneum is incised down toward the region of the uterine artery. This incision in the peritoneum meets the incision in the bladder flap and is eventually joined. The pull upon the ligatures on the infundibulopelvic and round ligaments tend to put the lateral peritoneum on tension. It may be necessary to place more clamps or traction sutures upon the edge of the lateral peritoneum. The medial peritoneum edge is now grasped in a clamp or traction suture and the nurse holds it, pulling the peritoneum toward the midline. This places everything on tension. (Throughout the operation tension is most important.) The ureter should be on the medial peritoneum but if it is not it can be easily found on the other leaf of peritoneum or in the muscular tissue over the large vessels. It is important to leave the *ureter on the medial peritoneum if possible, or dissect it so that* it will come to be in that position. If the ureter seems too free a clamp may be placed under the ureter and onto the medial edge of the peritoneum, thus keeping the ureter against that peritoneum. In freeing the ureter here and just beyond the bifurcation of the common iliac care must be exercised not to injure a small blood vessel and its vein arising from the internal iliac artery (hypogastric artery) and climbing up along the peritoneum to the ureter. The vessel is smaller than the lead in a lead pencil but is very obvious if looked for

Having opened the peritoneum and taken care of the ureter it is easy to start to free the areolar tissue of the under side of the peritoneum and over the large vessels. Starting upon the middle of the common iliac artery all the soft areolar tissue and many small and large nodes (depending upon whether or not they are involved) and lymphatics are dissected from the large vessels, leaving them bare. Often this dissection takes the operator to the lumbar muscles and on clearing them the genitocrural nerve is exposed. Occasionally, it is necessary to carry the dissection up the common iliac artery to remove apparent lymph nodes. The right common iliac vein lies in close proximity just behind and to the right of the artery and must be avoided. It is possible to dissect this whole area en bloc, dissecting downward toward the uterine artery The common iliac and the external iliac artery and its vein lying just below it are very easily freed of all areolar tissue and left clean. Lymph nodes have small blood vessels supplying

Preliminary Preparation. The patient selected for this operation is kept in the hospital from three to five days before operation Her blood chemistry is determined and her blood carefully studied. She is evaluated as a surgical risk by the hospital staff and if considered a proper risk is prepared for surgery. This preparation consists of the usual surgical preparations plus the use of an antibiotic for two days before operation. The antibiotic employed has been sulfanilamide in a few of the early cases, sulfapyridine in a small group, and most of the patients have had sulfadiazine. The drug is administered by mouth for two days before operation and a satisfactory level reached. It is then given intravenously after operation until the patient can again take it by mouth and it is then carried on for seven days after operation. Penicillin and streptomycin are now used routinely, and a sulfonamide as the occasion requires. In none of the 100 patients so treated did detectable peritonitis develop. This is very satisfactory for in the old days peritonitis was the usual cause of death.

Anesthesia. The patient is operated upon under gas-oxygen anesthesia, spinal or continuous spinal anesthesia. Each method is satisfactory but without doubt spinal anesthesia makes the operation easier.

Operation. The vagina is carefully dried out with gauze sponges and then double strength Schiller solution is poured into the vagina and carefully wiped out. The patient is then put on constant drainage by means of a Foley catheter which is left open to drain throughout the operation. This is done because at the end of the operation, when the uterus is to be removed, it is very desirable to have the bladder empty. The patient is then put in satisfactory Trendelenburg position and the operation begun. (It is important for the operator to stand upon the patient's left side for the description is given from that position.) A midline incision is used, carrying the incision about 2 inches above the umbilicus on the right. The fascia is incised down to the symphysis and the pyramidalis muscles spared. The abdomen is opened and an exploration carried out. If the lesion is considered operable the operation commences. It is our custom to remove the appendix next but this step can be eliminated if felt best. The abdomen is held open by a Balfour retractor. It is felt best to have a mobile retractor in the region of the pubis so the suprapubic blade is replaced by an ordinary retractor The uterus is grasped with a double hook. This is perfectly safe for there is no cancer in the endometrium and good traction is one of the most essential parts of this operation. The assistant now holds the uterus up tightly toward the upper end of the wound. The bladder flap is now raised, the peritoneum on the front of the uterus is lifted up, and the area beneath opened and a line of cleavage found. There is an adherent area in the midline in front of the uterus and this can be removed by scissors or knife or the finger can be passed from one opening on one side to the other opening on the other and then cut. The bladder peritoneum is now grasped with half lengths or Kelly hemostats on either side and throughout the operation the peritoneum of the bladder flap is held tense. The clamps lie easily upon the drapes at the lower end of the incision. The infundibulopelvic ligament and round ligament are then grasped in a curved hemostat close to the uterus Then a stitch ligature is placed through the bloodless area close to the round ligament and around

region. All the time this dissection is being done it is of the greatest importance to keep the uterus to the left under strong tension. It can be moved about as needed to give exposure to the part being operated upon. At this point the bladder is freed, the ureter is freed, the uterine artery is sectioned, the vesical artery is seen and occasionally other arteries to the bladder. The external iliac artery and vein are above and lateral. The ureter is attached to the peritoneum from above to just below the small hypogastric artery that is so essential to the ureter.

In the early cases the ureters were catheterized and the ureteral catheters left in place. It was found that this was not necessary and perhaps it might do more harm for the ureter was apt to be more easily traumatized. Sponges seemed to stick to it more easily and when trying to pick it up to keep it on slight tension the ureter would be bruised on its inside by pressure from the forceps against the ureter against the catheter. The catheters were given up and have never been missed. (For beginners in this operation it is well worth while to use small and soft ureteral catheters. The ureter can also be held up by means of tape and various types of encircling clamps but it is very important to touch or pull upon and abuse the ureter as little as possible.) Since finding the blood supply, and avoiding catheters and tapes about it we have had no ureteral injury. The blood supply to the ureter from the uterine artery and from the vesical artery are of necessity destroyed in freeing the ureter from the bladder and uterine artery. As the ureteral arteries enter the ureter at right angles and run up and down it forming an anastomosis it is essential that not more than two arteries in a row be cut, therefore the importance of preserving the small hypogastric branch.

The next step, keeping the uterus on left lateral tension, is to try to open and clean out the obturator foramen. This is important for in our series there were more obturator nodes involved than any other group. The obturator foramen lies directly under the last one-third of the external iliac vein. This vein can be gently retracted upward and outward and a mass of fat or nodes will be found filling the obturator foramen. This mass of fat and nodes is not uncommonly attached around the obturator nerve that crosses the foramen. This nerve is always seen after dissection of the foramen for at least 1½ to 2 inches. With the finger or with scissors the dissection is begun in the foramen and slowly a large mass of fat and nodes can be removed. Occasionally only fat appears but more often fat and nodes, though the nodes may not be positive. Care must be taken not to injure the base of the foramen for there are large branches here from the hypogastric vein and injury on one of these veins might make it very difficult to stop a hemorrhage from them. After the obturator foramen is cleaned out the dissection on the right side is finished. It is now necessary to do the same thing on the left and this dissection is made more difficult because of the position of the sigmoid and its mesentery and blood vessels. In most instances the sigmoid can be pushed toward the midline and upward and the common iliac artery located, but in other instances the dissection starts upon the bifurcation of the iliac arteries and goes down in the usual fashion from there The rest of the dissection is identical for the left side as for the right Occasionally it is easy to go to the other side

them and it is occasionally necessary to clamp below the nodes and tie the small vessel off and thereby not stain the field with blood. The fat and nodes about the lower end of the external iliac artery should be removed. It is now the time to place a clamp for traction upon the medial peritoneal edge about one inch from the uterine artery as it extends to the side of the uterus. Traction upon this piece of peritoneum will pull the ureter medially and it should be identified for it will come upward with the traction and must eventually be freed from the peritoneum at this level. In dissecting the fat and areolar tissue in this region while everything is on tension the obliterated hypogastric artery is exposed leading back to the hypogastric artery and as it is being freed the uterine artery arising from the hypogastric is exposed. The uterine artery may arise from the obliterated hypogastric or directly from the hypogastric. Care must be taken not to clamp the vesical artery, mistaking it for the uterine. The uterine must be identified and clamped, cut, and tied at its origin. The uterine artery is noticeably small and can be easily tied once or twice with fine catgut or cotton or silk. A clamp is placed upon its distal end and it is pulled upon the side of the uterus and held under tension. The uterine vein is not always seen here but the area must be carefully dissected and the vein looked for, for there may be numerous small veins (uterine) that will cause a lot of troublesome oozing. A large amount of fat containing numerous veins runs from the lateral edge of the bladder to the area of the uterus where the uterine artery enters the uterus and above the ureter as it runs under that uterine artery. One is tempted to cut this innocent looking fat but there are numerous small veins in it that must be ligated. Some operators try to place the index finger under the mass and it looks very easy to do and occasionally can be done but in other instances it is impossible. It is safe to clamp and divide it in small pieces for the ureter is well below it, deep in a channel of its own. This corner of bladder and uterus is definitely troublesome but with care and careful dissection it can be well cared for.

The ureter is now attached to the medial peritoneum and the uterine artery has been lifted above it. It is now necessary to free the ureter out of its channel to the bladder. This is done by freeing it from the peritoneum and putting it on very slight tension by grasping some of the areolar surrounding it with a pair of smooth forceps. It can be easily followed as it dips into a definite connective tissue canal that is present in every case. There is a temptation to place a pair of scissors into the canal and cut the roof of it. This might be done but the ureter is adherent to the canal by firm adhesions and it might easily be cut by too vigorous an attempt to just cut the roof of the canal. The placing of curved Kelly's or half lengths in this canal and cutting upon it is also to be condemned for the same reason. It is best with gentle traction on the ureter to free it piece by piece from its canal above, laterally and behind. The ureter will be found adherent to the base of the canal as it crosses the lower cervix or upper vagina. The fine adhesions holding it in place must be cut and freed. Eventually without serious trauma to the ureter it can be entirely freed from its attachments and can be seen running toward the bladder. The bladder must be dissected far enough off the vagina to allow dissection of the ureter to the bladder. This area can be found because the ureter fans out at this particular

stitch and left open. No drain is necessary. Sulfanilamide is not used in the pelvis. At this point the whole area is inspected and it is extraordinary how clean the whole pelvis is and what a satisfactory dissection has been done. If no bleeding is present the peritoneum is closed. This is done by means of a running continuous stitch of No. 0 catgut from the right angle at the peritoneal opening across the pelvis to the left angle. No attempt is made to support the vagina with any ligament or structures sutured to it and there has been no prolapse of the vagina in spite of the fact that the perineum is not sutured and repaired Scar tissue formation must be very strong and gives satisfactory support. The wound is then closed in the usual manner and the patient sent to the ward During the operation and especially toward its end it is necessary to give the patient whole blood. This is a very essential and necessary part of the operation. Shock develops only if insufficient blood has been given and it is essential to replace blood loss with whole blood. The patient is kept upon constant drainage for 7 to 10 days after operation and is permitted out of bed whenever she feels like it, there being no definite rule as to when she may get up.

CARCINOMA OF THE VULVA

General Considerations. Where any ulcerating lesion of the vulva proves on biopsy to be carcinoma the operation of choice is a radical vulvectomy combined with an en bloc dissection of the superficial inguinal and femoral nodes. To this should be added an extraperitoneal dissection of the vaginal nodes found above Poupart's ligament along the external iliac artery and vein and in the obturator space. Because these patients are in the older age group *this extensive procedure can safely be performed in relatively few* instances as a single stage operation. If the operation is to be staged the logical move is to combine a radical vulvectomy with en bloc dissection of the superficial inguinal and femoral nodes. Spread to these nodes is most direct and they will be involved in approximately 50 per cent of the cases seen. These are older patients with a will of their own. If given any encouragement they will not return for a second stage of their operation. The majority of the patients, regardless of their age and general condition, will tolerate surgery of this extent. This much should be done with the hope that the deep nodes will also be removed at a second stage. There remain a few patients who are either in too poor condition or too old to tolerate more than radical vulvectomy.

VULVECTOMY

Indications. Where any ulcerating lesion of the vulva is noted and biopsy reveals carcinoma a total vulvectomy is indicated. There is no place for a partial vulvectomy or hemivulvectomy in malignant disease of the vulva. In addition to cancer of the vulva, vulvectomy should be performed for such precancerous lesions as leukoplakia and kraurosis.

Observations. The dissection should be radical and include both labia extending to the fascia in its depth. A sharp knife is the best instrument, though electrosurgical dissection may be carried out. The disease is prone to recur whether it be malignancy or leukoplakia, and wide *margins must*

of the table to properly visualize and operate upon the left obturator foramen. Once the left dissection is completed the uterus is pulled upward toward the upper angle of the wound and the bladder is dissected free well down upon the vagina. This is easy to do for all the dissection has been completed and the ureters, the really great danger, are under direct vision.

The bladder having been freed sufficiently the next attack is upon the posterior cul-de-sac. The uterus is pulled downward under tension over the symphysis and the sigmoid and upper rectum are pulled upward with gauze over its surface. This puts the cul-de-sac on stretch. It may not be necessary to remove the cul-de-sac but as cervical cancer is so very close to it and as it can easily penetrate this region and spill into the cul-de-sac it has been our custom to remove it. The peritoneum over the rectum is opened on the lateral side of the bowel and lines of cleavage toward the posterior vagina are established. The peritoneum is then grasped with Kelly forceps or half lengths and put on tension and the attachments of the cul-de-sac to the sigmoid and upper rectum are seen as bands and can be dissected off the bowel without too much danger. In but one instance was the bowel entered and it was closed easily with no untoward reaction. Care must be taken when freeing the peritoneum laterally not to catch the ureter where it is attached to the peritoneum and care must be taken not to injure the small ureteral blood vessel that comes from the hypogastric. The uterosacral ligament is cut across low down below the peritoneum as far away from the uterus as possible. Large Moynihan clamps are conveniently used for this procedure. After the rectum has been fully freed off the posterior vagina and after the uterosacral ligaments have been severed the remaining structures, the pillars of the vagina, the ligaments, and muscles that make up their support are clamped and cut. Starting laterally with clamps it is easy to clamp and cut free almost the entire vagina. In the lateral regions of the field care must be taken not to be too radical and clamp the hypogastric artery. The middle hemorrhoidal vessel is usually clamped and cut but a too free dissection here can get the operator into serious trouble with the hypogastric vessels and it is not necessary for everything stands out so clearly and well at this time.

After clamping and cutting the vaginal supports and attachments, the vagina itself is approached. A clamp is not used below the cervix, for we feel that we can remove a larger amount of vagina without a clamp. It is acknowledged that a clamp might prevent spillage of tumor cells but spillage has already occurred into the vagina during the operation from the desquamating tumor. The vagina is opened laterally and it is easy to remove a large amount of the vagina. The bladder may interfere with removal of the vagina but it is easy to push it out of the way. With the Foley catheter in place it is easy to locate and empty the bladder satisfactorily to help dissection. The clamps on the vaginal supports are tied off with stitch ligatures and the whole pelvis examined for bleeding points. In only one of our cases was there a postoperative hemorrhage and this necessitated opening the abdomen again and ligation of vessels running up and about the sigmoid. After all the pelvic vessels are tied the vagina is sutured along its edge with a continuous suture as a hemostatic

stitch and left open. No drain is necessary. Sulfanilamide is not used in the pelvis. At this point the whole area is inspected and it is extraordinary how clean the whole pelvis is and what a satisfactory dissection has been done. If no bleeding is present the peritoneum is closed. This is done by means of a running continuous stitch of No. 0 catgut from the right angle at the peritoneal opening across the pelvis to the left angle. No attempt is made to support the vagina with any ligament or structures sutured to it and there has been no prolapse of the vagina in spite of the fact that the perineum is not sutured and repaired. Scar tissue formation must be very strong and gives satisfactory support. The wound is then closed in the usual manner and the patient sent to the ward. During the operation and especially toward its end it is necessary to give the patient whole blood. This is a very essential and necessary part of the operation. Shock develops only if insufficient blood has been given and it is essential to replace blood loss with whole blood. The patient is kept upon constant drainage for 7 to 10 days after operation and is permitted out of bed whenever she feels like it, there being no definite rule as to when she may get up.

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Observations. The dissection should be radical and include both labia extending to the fascia in its depth A sharp knife is the best instrument, though electrosurgical dissection may be carried out. The disease is prone to recur whether it be malignancy or leukoplakia, and wide margins must

be given to the disease process. All areas of leukoplakia must be removed even to the area between the fourchette and the anal opening. A definite warning should be given that the eradication of the disease is of prime importance with plastic closure second. Relaxing incisions or flaps may be constructed or the vagina left open to granulate, but adequate excision is imperative.

Operation. A wide elliptical incision is begun at the mons veneris in the midline above the clitoris at the apex. The incision then passes downward on either side extending laterally to include both labia down to a point in the midline just below the fourchette. If the diseased process is leukoplakia and extends down to the anus this skin likewise must be sacrificed. It is well to outline only the skin incision first lest the field become too covered with blood.

The external incision outlined, the next most important step in the operation is to expose the vaginal mucosa within the introitus and outline the incision within the vaginal canal by beginning the incision through the vaginal mucosa above the urethral opening in the midline and carrying it down as an ellipse on either side to meet in the midline posteriorly just within the fourchette. This step will greatly aid the surgeon in orientation later.

Allis forceps or rake retractors are then placed on the lateral cut skin edge. The dissection is then carried down through the fat to the fascia of the underlying muscles. Many blood vessels are encountered which can be individually ligated if sharp knife dissection is done and countertraction is applied on a flat plane by the assistant. It is well, in order to enjoy a dryer field, to begin the dissection from below upward as far as possible. The individual bleeders may be controlled by tie or stitch ligature. After the dissection is completed on one side, it is duplicated on the opposite side. Next the process of connecting the lateral incision with that made within the vagina is begun from above in the region of the pubis. The landmarks are definite and the cleavage plane is more apparent. The dissection proceeds from the lateral side toward the midline. It is at this point that the value of the early outline of the limits of the area to be excised within the vagina becomes apparent.

Closure of the wound is accomplished by approximating the skin edge to that of the vaginal mucosa with interrupted silk sutures. By reducing the extreme lithotomy position and allowing the legs to come together slightly this step is frequently made easier

Care must be taken not to suspend the urethra at a bizarre angle when performing the plastic closure.

An inlying catheter of the Foley type is inserted in the urethra and a firm pressure dressing obviates the need of a stab wound drainage.

RADICAL VULVECTOMY AND SUPERFICIAL GROIN DISSECTION

If the complete dissection of both superficial and deep nodes as an en bloc dissection in combination with radical vulvectomy cannot be safely performed the ideal method of staging the operation should include the bilateral removal of the superficial inguinal and femoral nodes together

with radical excision of the vulva. The dissection must be bilateral regardless of the location of the primary lesion, for the lymph channels decussate from one side to the other. The network of intercommunicating lymphatic channels is so extensive that the surgeon cannot concentrate on a one sided dissection.

Technic. INCISION. The use of a circular incision extending from one anterior superior spine of the ilium to the other with the lower part of the arc following the crease of the groin will avoid many of the unpleasant complications noted in the use of other types of skin incision. So much undermining of the wound is necessary that when combined with the essential removal of large blocks of fat and lymphatic tissue, collection of serum, wound breakdown, and skin necrosis are common and distressing complications. It has made little difference whether the dead space has been obliterated by pressure dressings on the groins immobilized by spica type bandages. The circular incision does not ensure primary skin union. Where necrosis of the skin edge appears it tends to be in the midline over the symphysis away from the femoral vessels. In this area grafts can easily be applied on the fine base rather than having to delay the wound closure until a firm bed of granulations has developed over the vessels. Lymph edema is rare in the cases where bilateral groin dissections have been done using the circular type of incision.

DISSECTION. The skin edge is protected with gauze. The edges are then undermined in a plane just above the superficial fascia well upon the abdominal wall. The deep layer is then dissected downward off the fascia overlying the external oblique muscles on either side.

The lower skin flap is then elevated with rake retractors and the edge undermined in the same plane noted above. Separation of the deep fatty tissue from the superficial fascia continues down the thigh as far as the top of the adductor canal The deep fatty tissue contains both the lymphatic channels and the nodes. The lower flap is held on traction in an upward direction to allow the surgeon to employ scissors in dissecting the mass of tissue off the underlying fascia, beginning laterally and moving medially toward the femoral vessels. The mass is dissected free from Poupart's ligament as far as the vessels Attention now turns to the distal part of the dissection. The saphenous vein is found lying on the medial side of the femoral vessels. It is clamped, divided, and doubly ligated.

The dissection continues medially upward toward the vulva, stripping it off the underlying fascia. Careful dissection is now required to remove the mass of lymphatics, fat, and nodes from the femoral vessels. The sartorius muscle lying laterally is identified and an incision made in the fascia overlying its medial border. The entire muscle edge is exposed. The femoral artery lies just medial to it and can be identified by palpation. Its sheath is then incised on the lateral side. The mass is then dissected off the femoral artery by staying in a plane close to the artery. The dissection proceeds along the lateral side of the artery to Poupart's ligament, clamping and securing any small arteries that may be encountered.

In many instances the entrance of the saphenous vein into the femoral is obscured by a mass of nodes involved in disease. A small artery crosses the femoral vein just below the junction of the two veins. It is constant

and should be sought for as a landmark. The chain of nodes lying between artery and vein are now dissected free, exposing the wall of the vein as the femoral sheath is incised and separated from the vein. The saphenous vein and its many branches can then be identified at its junction with the femoral. It is isolated and doubly clamped. It is important not to tent the femoral vein in applying these clamps. The vein is then divided, ligated, and further secured with a stitch ligature.

The mass of fat and nodes is then completely dissected free of the vessels along the medial side. It is along this side of the vessels that the lymphatic channels pass to the nodes above Poupart's ligament. The block of tissue is further mobilized medially toward the spine of the pubis.

An intermediate chain of nodes extends along the round ligament. For this reason the external oblique fascia is divided in line of fiber to the point where it enters the peritoneal cavity. Any nodes are removed and incorporated in the main mass of the tissue. The round ligament is divided, sutured, and the fascia closed.

The same dissection is carried out on the opposite side.

The upper and lower skin flaps are now brought together at the corners by first suturing the superficial fascia and then the skin.

The dissection has been en bloc on both sides. The mass is now concentrated in the midline and is part of the specimen containing the primary tumor which must now be removed. At this point the patient is placed in the lithotomy position. The steps of the radical vulvectomy are then carried out and the entire specimen, including the bilateral nodal masses, is removed. Drains are placed on either side of the reconstructed vulva through stab wounds and an inlying catheter is placed in the bladder.

EXTRAPERITONEAL LYMPHADENECTOMY FOR CANCER OF THE VULVA OR CERVIX

In the radical groin dissection the nodes deep to Poupart's ligament, those lying along the iliac vessels, and those in the region of the obturator space should be removed at the same operation. This operation, combined with the superficial groin dissection, should be carried out as the procedure of choice for cancer of the vulva.

An additional indication has recently been introduced for the treatment of the regional nodes involved in carcinoma of the cervix. If the operation is to be done for cancer of the cervix it is to be performed without the preliminary superficial groin dissection The ease of this operation will be greatly facilitated by insertion of an inlying catheter preoperatively.

Operation. When this operation is done in combination with the superficial groin dissection the skin incision has already been made. In its use for nodes of carcinoma of the cervix (these are the same nodes involved in cancer of the vulva or clitoris) an oblique incision extends from the anterior-superior spine to the spine of the pubis.

In either case the fascia of the external oblique is now exposed. The external inguinal ring is identified and the fascia divided in line of the fibers. The round ligament is retracted medially or divided if desired.

The internal ring is located and the gloved finger is introduced into the

opening and the muscles freed from the underlying peritoneum by blunt gentle dissection with the finger (Fig. 20-50). These muscles are then divided, taking care to ligate individual vessels as they are encountered and leaving enough muscle below to permit easy closure with mattress sutures in the final reconstruction. The same maneuver is carried out medially with section of the muscles to the conjoined tendon.

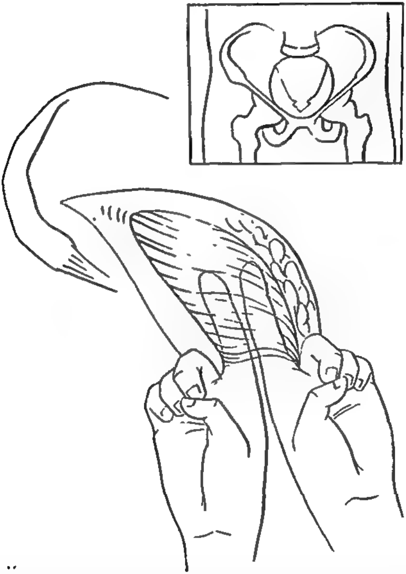

Fig. 20-50. The external oblique fascia has been divided The gloved finger has entered the internal ring, pushing the peritoneum from the under surface of the muscle. The fibers will be divided between the fingers, leaving a cuff on the distal side to facilitate reconstruction

The most important step in the operation now follows. Immediately medial to the round ligament, lying along the medial border of the internal inguinal ring, the deep epigastric vessels are encountered. Division of these vessels close to their origin from the external iliac vessels permits retraction of the peritoneum with the rest of the abdominal wall upward and medially, exposing the nodes in relation to the iliac vessels (Fig. 20-51). The nodes lie in the fat surrounding the vessels.

The dissection is begun at the level of the bifurcation of the iliac vessels on the lateral side working medially as the dissection proceeds (Fig. 20-52). A long, thin scissor with blunt end is the most useful instrument.

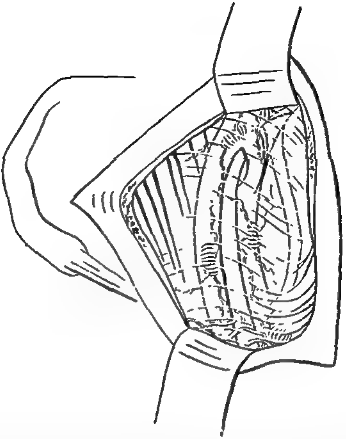

Fig. 20-51. The deep epigastric vessels have been divided and the peritoneum stripped upward to expose the iliac vessels with the overlying fat containing the nodes. The ureter may be seen along the medial edge of the exposed cavity lying along the peritoneum and entering the bladder The bifurcation of the iliac is obvious.

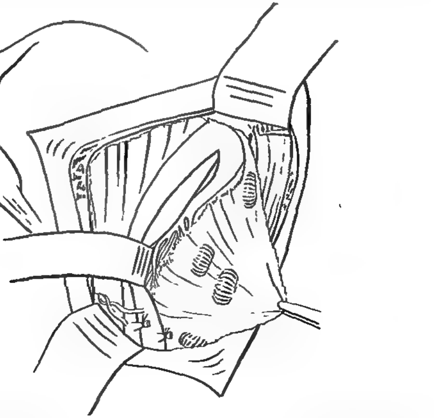

Fig. 20-52. The dissection of the nodes has been begun from above downward, beginning at the bifurcation of the iliacs The dissection proceeds from above downward and from without inward. The ligated, deep, epigastric vessels may be seen at the inguinal ligament.

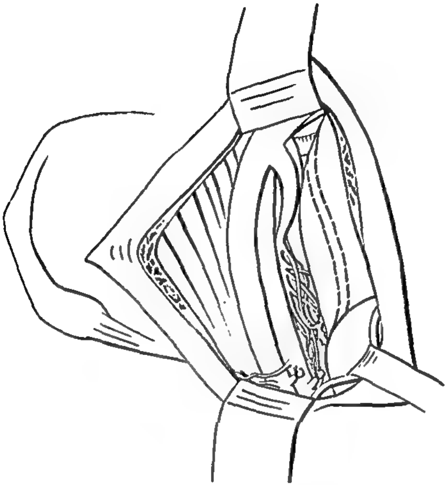

Fig. 20-53 The dissected hypogastric plexus is now cleared of nodes to expose the terminal branches of the vesicle and vaginal branches The vessels will be retracted laterally to expose the obturator space lying beneath, with the obturator nerve coursing through it.

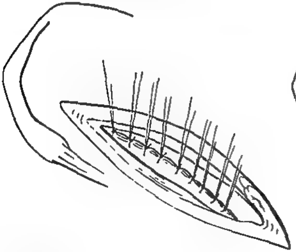

Fig 20-54 The underlying fascia and muscle have been closed with interrupted cotton or silk

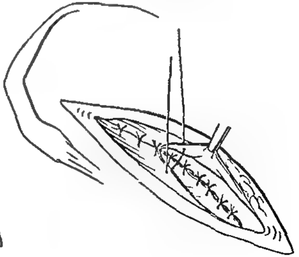

Fig. 20-55 The reconstruction proceeds as in a hernia repair

As the dissection progresses the deep concavity of the pelvis is visualized. The retraction of the ureter with the medial wall of the peritoneum allows for division of these prolongations of perivascular fat without fear of damage to important structures.

Lateral and deep to the external iliac vessels the obturator space is encountered with the obturator nerve seen running as a taut string across the middle of the space (Fig. 20-53). A large node is usually encountered in this space lying in relation to the lower innermost end of the exposed obturator nerve. Near the stumps of the deep epigastric vessels at the point of origin from the iliac more nodes are encountered. By sectioning these vessels as they come off the wall of the iliacs the areolar tissue with nodes are readily removed.

The dissection is carried down medial to the vein to contact the dissection previously completed from below Poupart's. It is here that Cloquet's node is removed.

The entire wound is irrigated with saline and bleeding controlled. The entire wall is then reconstructed as in a hernia repair (Figs. 20-54 and 55). Pressure dressings are applied.

It is possible to do bilateral dissections at the same operation. It is wiser, however, to divide the operation into stages, doing one side at a time. This is particularly true in cancer of the vulva when the upper and deeper dissection is combined with the lower superficial dissection.

21

THE MALE GENITOURINARY SYSTEM

D. K. Rose

ANATOMIC CONSIDERATIONS

We are dealing with a system of associated function from kidney to urethral meatus; this functional interrelationship is such that urethral, bladder, prostatic, or kidney surgery may have a definite effect not only upon the organ operated but also upon another part of the genitourinary tract. From above downward in surgical importance we consider the urinary tract as kidney, with its calyces, pelvis and ureteropelvic junction, the ureter with that portion which traverses the bladder wall, the intramural ureter, and also the ureteral orifices, closely associated with bladder; then the bladder and its internal orifice, the urethra, divided into prostatic, membranous urethra, and anterior portions, and last, the urethral meatus.

The kidney is normally located so that the twelfth rib passes behind its upper third. It maintains this position by virtue of the sulcus made by the arch of the ribs, by pressure of normal belly wall muscles, and by its perirenal fat and Gerota's fascia. A kidney may be long and narrow or short and thick, and its pelvis may be intrarenal or extrarenal with high, middle or low attachment. These factors influence the disposition of its intrarenal drainage system, the major and minor calyces. The maintenance of the normal kidney position is important, so that the given length of ureter should have a direct downward course in its freely movable location, which is within the retroperitoneal fat.

The amount of urine passing through the pelvis of the kidney varies greatly, the small pelvis must have more rapid flow than the large. Suspiciously at times the small, more intrarenal pelvis, when disproportionately divided for equal flow of urine, may be important from the standpoint of nephralgia, stone formation and infection (the "dysuric" pelvis) while the large, elastic extrarenal pelvis may be important from the standpoint of stasis of urine(1). The ureteropelvic junction is a site of both congenital and acquired constriction, and therefore for plastic surgery.

In the lower ureter the intramural portion is of greatest importance, as it is directly influenced by the thickness or the thinness of the bladder wall. The direction or course of the ureter through a normal bladder wall may be of importance. However, if a bladder is obstructed, and so becomes compensated, thickened, to a slowly progressive obstruction over many years, as a result of overwork(2, 3), then the course of the ureter can have definite importance. In this regard we have seen instances in which, after cystostomy, the collapsed, and therefore thickened, bladder wall required that ureteral catheters be passed through the cystostomy wound and into

the blocked ureter to relieve a sudden rise in blood nonprotein nitrogen which occurred 48 hours after operation, due to a pinch, by the bladder, of the ureters in their intramural portion. Angulation of the ureter at its entrance into the thickened bladder wall is an accessory factor in this type of ureteral obstruction.

The ureteral orifices are important as to their location, number and size. When too small they may require incision; however, such an incision may subsequently allow regurgitation of urine to the kidney pelvis, with or without nephralgia(4).

The urinary bladder has a transitional epithelium which, by virtue of its submucosa, can slide over the muscularis, thereby adapting to the varying sizes of the dilating or contracting bladder. The trigone, that area bounded by the ureteral orifices and the bladder outlet, has no submucosa and, therefore, remains a flat platform at all times. This platform bears a thin muscle which emerges from the outer longitudinal muscle layers of the ureters to fan out, pass through the internal orifice and insert into the posterior urethra. This, the trigonal muscle, by contraction effects some widening and lowering of the floor of the internal orifice, but chiefly smooths down the mucosa of the internal orifice and proximal posterior urethra. The bladder musculature is interwoven, spindle-like bundles of smooth muscle, which are fine and numerous at the bladder dome, become fewer and thicker toward and on the floor of the bladder, particularly at their insertion along the edges of the trigone. The internal orifice is a thickened, circular area of the bladder wall rather than a distinct anatomic and individual sphincter.

The posterior urethra in the male contains the verumontanum from which we occasionally find congenital folds of mucous membrane extending upward and laterally to the internal orifice. These folds may be obstructive. The membranous urethra, just anterior to the prostatic urethra, is a favorite site for stricture; while anteriorly from this area we find the bulbous, then the pendulous urethra with its meatus which must be sufficient in size. Interrelationship of every one of these units, one to the other, and above all, to the kidney itself, should at all times receive consideration in urologic surgery.

SYMPTOMS

Kidney pain may be located at the costovertebral angle or abdominally along the course of the ureter, or referred to the testicle, the penis, groin, and thigh. Occasionally a very atypical kidney pain occurs, as when referred to a shoulder, elbow, middle of the back, or umbilical region. Three types of renal pain should be considered 1, when due to back pressure, ureteral or pelvic overdistention, 2, when due to ureteral spasm which is particularly severe upon passage of a small stone, 3, a less frequent and less severe type is displacement pain, caused by pressure upon a neighboring organ. Pain may be caused by the kidney enlarging, a compensating remaining kidney after removal of its mate, or by an infarct, a passive renal congestion or a sudden ischemia, or psychogenic vascular reflex, associated with violent emotion. An established hydroureter or hydronesphrosis seldom is painful due to back pressure anesthesia.

Bladder symptoms may be interpreted entirely upon a physiologic basis. The expulsive force of the bladder varies with its requirements, and with its ability to meet these requirements. The function of the bladder is to empty itself, and it will attempt to empty according to its ability to accommodate urine, that is, its elasticity, thickness and irritability. Painful frequency and urgency of urination may be caused by a true cystitis. However, frequency, urgency and pain with urination may be due less frequently to loss of elasticity of the bladder wall caused by a Hunner ulcer, endometriosis, a pericystitis, or reflexly from a urethritis. Ability to initiate and maintain a urinary stream depends upon the strength of the bladder wall, which forces the urine through either a normal or obstructed outlet. The state of dilatation or contraction of the bladder is important for this function; for example, an individual with an early prostatic obstruction will have an excellent urinary stream during the day when his bladder wall is sufficiently thick, and therefore sufficiently strong. In the morning, upon awakening, when, due to sleep he has allowed his bladder to overfill, however, his urinary stream at first may be weak; the wall then is too thin by overstretch to force urine in a continuous stream through his partially obstructed prostatic orifice.

Incontinence of urine depends upon many different alterations in function. Incontinence of urgency may be due to irritability of the urethra, reflexly stimulating the bladder to sudden contraction, or may be due to an irritated bladder which resents the weight of the urine upon its irritated surface, with or without an associated urethritis. Incontinence of urine without the patient's knowledge suggests a deficient sensory system, that is, a neurogenic cause. In order to interpret these symptoms it must be necessary to have in mind a definite physiologic scheme of bladder function, that is, the steps, one by one, from the first desire to urinate to completion of the act of micturition. Such a conception, presented under functions of the bladder (page 912), will enable us to interpret the symptoms we may encounter, either preoperatively or postoperatively, in our urologic surgery.

A Method for Diagnosis. In the approach to urinary surgery one must have a method of diagnosis that will eliminate pitfalls inherent in such associated physiology as we have within the genitourinary tract. The following outline is used in our Out-Patient Clinic and if followed will lead unerringly to a diagnosis of pathology or of an interrupted normal physiology. The four "boxed in" and most important diagnostic findings quickly orient the urologist at each visit of the patient and so direct further investigation until the final diagnosis is reached.

Reasons for these Diagnostic Steps and their Sequence. 1. Glass 1 represents the wash from the urethra added to the urine of the bladder. Glass 2 represents urine from the bladder passing through a washed urethra. Stain of glass 1 will occasionally show some fine organisms that are intracellular, "urethral" in type, bacilli, smaller than we usually see; and cocci are found in small clumps in and near epithelial cells. On the other hand, organisms scattered through the microscopic oil immersion field grew *in* the urine and not *on* the mucous membrane. A combination occurs. Urologists determine the presence and type of bacteria, not just the presence of pus cells

the blocked ureter to relieve a sudden rise in blood nonprotein nitrogen which occurred 48 hours after operation, due to a pinch, by the bladder, of the ureters in their intramural portion. Angulation of the ureter at its entrance into the thickened bladder wall is an accessory factor in this type of ureteral obstruction.

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2. Palpation of the prostate in the male, or manual palpation of the kidneys before the male or female voids, may cause scattered red blood cells to show in the urine. Therefore, obtain the urine specimen before doing either of these procedures.

Note anal sphincter tone; spastic, atonic or quite normal; when stimulated by the finger, it may become reflexly spastic or open widely. As the anal sphincter and the anterior perineal muscles are both of sacral innervation (N. pudendus) it is evident that dysfunction of an anal sphincter suggests dysfunction of the voluntary bladder sphincter mechanism, which is most important in neurogenic dysurias.

UROLOGY

Patient's name Date W.C. M.S.W.
Address Age Clinic number
Clinic

Referred by ____________
Examined by ____________
Supervised by ____________
Tentative, first visit, diagnosis ____________
Final clinic diagnosis ____________
Hospital diagnosis ____________ Date ________
Diagnosis checked by secy. name ____________ Date ________

Most Important Subjective Symptom
Most Important Objective Finding
Positive Urinary Findings
Residual Urine

History Present complaints—"Onset with"________ "When"________
Past history—
Family history—
Present illness—

Physical examination—observe nutrition, gait, reflexes.
palpate kidneys after obtaining urine specimens.

1. Urethral smear—Gram stain or methlyene blue stain—staphylococci and gonococci may be indistinguishable without a Gram stain.

2. Male glass 1 and 2—(methylene blue or Gram stain of glass 1 shows urethral infection with or without infection of THE URINE, determined by stain of glass 2)
(Catheterized specimen, female)
Complete urine Appearance Alb. Sug Casts
ph RBC Methylene blue stain Bacteria WBC

3. Rectal examination—sphincter tone.
prostate.
s. vesicles.
Microscopic prostatic secretion { *high power dry.*
{ methylene blue or Gram stain

4. Residual urine—amount.

Perform steps 2—3—4 in rapid sequence THEN—make laboratory examinations of urine and prostatic secretion.

5. Special examination (female)—catheterize for urine specimen, have patient void, catherize for residual urine.

Urethra | Urethrocele | Vaginal mucosa
Meatus | Prolapsed mucosa or caruncle
Bladder base | Cystocele
Perineum—rectocele

Instrumentation—1. Sounds, etc. urethra | Bladder capacity
2. Cystoscopic
Ureteral catheters | Rt. kidney urine | Stain | Culture
Lt. kidney urine | Stain | Culture

Differential kidney dye test | Rt. kidney | Lt. kidney
Appearance | Papanicolaou stain
Total excretion

X-ray—Retrograde | Pyeloureterogram
Cystogram | Urethrogram
Overflow—

3. Cysto—Urethroscopic

X-ray—Intravenous pyelogram | Ureterogram
Cystogram | Nephrogram

Results of hospitalization—diagnosis
Positive laboratory findings—
Treatment recommended or refer—

3. Catheterization of a male for a residual urine determination before palpation of the prostate probably will cause red blood cells to appear or be increased in the expressed prostatic secretion. Catheterization for a residual urine may decrease or cause a fairly well established or early residual urine to disappear for days or weeks. The test should not be made if the patient has drunk too much water as kidneys can excrete 30 ml. per minute per kidney—a constant residual urine of 30 ml. could maintain a bladder infection, so there may be but this one opportunity to determine its presence.

Urine for methylene blue stain and for residual urine determination should be concentrated to at least an amber color.

4. In the female, catheterize for a 10 ml. specimen first, for if there is no residual urine then a specimen for microscopic examination is lost. All adult female voided specimens show WBC and vulval organisms. Methylene blue stain of a specimen incubated in the patient's bladder for one, two or three hours is the most accurate method for determining the presence of an infection. A pH determination often helps to tentatively identify an organism and suggest the best immediate treatment.

Today we must know the infecting organism and its sensitivity to various urinary antiseptics. It is well known that penicillin is not of value against the colon bacillus, the organism which accounts for a large percentage of urologic infections.

In the adult female we catheterize to obtain a specimen for microscopic examination. Then, as the patient voids, it is well that she be left alone so there will not be a psychic retention of urine. Immediately the patient finishes voiding she should be placed back upon the table and catheterized

for residual urine to prevent any refilling of the bladder by kidney output, which could be mistaken for a residual urine.

Our clinical culture of urine often is faulty positively or negatively in 15 or more per cent of cases, as: 1, skin contamination is easy; 2, certain concentrations of bladder urine may reduce the viability of the organism; 3, delay in planting the culture, meanwhile with exposure to unfavorable temperature, may bring in a false negative culture report; 4, the presence of a trace of some urinary antiseptic taken by mouth one, two or three days before examination may cause a false negative report to be returned; and 5, ureteral catheter specimens with a definite bladder infection are very frequently contaminated and so give a false positive culture of the kidney urine.

The infant female need not be catheterized, even for methylene blue stain In the adult female, however, the voided specimen is entirely without value from the standpoint of stain, as bacteria, often with pus, is always picked up from the outside in the passage of urine. In urology we must look for the organism and not only for pus cells. The fireman is interested in the fire, not the smoke!

This completes the essential steps, in proper sequence, for the establishment of many diagnostic points(37, 38). If there is a residual urine, an intravenous pyelogram, when indicated by the patient's history, may determine the status of the upper urinary tract more safely than cystoscoping and passing ureteral catheters through an infected bladder which carries a residual urine. On the other hand, if there is no residual bladder urine and we find a definite subacute, chronic, or recurring cystitis, it is necessary to determine whether the upper urinary tract is infected, and in that case to carry on through the cystoscopic examination, as outlined in the Method for Diagnosis.

The Papanicolaou stain promises to be of great aid in urology as well as other specialties. The work of Foot and Papanicolaou(31) in which they demonstrated malignant cells in the urine of a kidney which when removed did not show cancer on gross inspection is a very significant finding because cancer of this kidney was present on microscopic study. This work lends support to the work of Papanicolaou and Marshall(32) reporting malignant cells in the urine in cancers of the urinary tract. Urologists know that urinary malignancies must be discovered early, while a localized disease, if they are to effect a more and more favorable percentage of cures in these cancers This test requires the services of a trained pathologist. The test offers great promise, although a negative report is not conclusive. If cancer is suspected a complete diagnostic procedure should be completed without delay.

THE KIDNEY AND URETER

Having established the site of pathology, with its effect locally and to the entire urinary tract, and therefore, to the complete psychophysical economy of our patient, we direct our surgical efforts to correct completely or as completely as possible, the very basic pathologic factor upon which all other pathologic and physiologic changes rest. This means attempting to correct entirely, and not merely to improve, the flow of urine

throughout the entire urinary tract, to remove all pathologic tissue, to minimize and place our postoperative scar tissue so that we may hope for return of normal function of the entire urinary tract. Without return of normal urinary flow, the mucous membrane or the urine having once been infected will remain infected or reinfect. We normally excrete in the urine all types of organisms, passing them over the surface of the mucous membrane without its becoming infected or invaded. This can occur because the mucous membrane is protected by local and general immune factors, which may be broken down by irritating drugs, violence of infection, direct physical injury such as catheter, or because there is stagnation of urine allowing time for an overwhelming multiplication of the organism.

Nephrectomy (KIDNEY + EXCISION). Under all conditions the urologist attempts to preserve the largest per cent of normal or near normal kidney function. This may be done by removing an irreparably damaged kidney when its mate is normal, or it may be done by removing a portion of a kidney; performing a calyxectomy or a heminephrectomy.

In kidney surgery the incision should be ample, so that the vascular pedicle is accessible, should hemostasis suddenly become necessary, and also that freeing of the kidney or the necessary portion can be accomplished without unnecessary traction upon the pedicle. Resection of the twelfth rib, very rarely the eleventh rib, may be necessary to secure adequate exposure. Whenever the kidney is partially fixed by scar tissue it may be removed within its capsule (subcapsular) with greater facility than insisting upon resection of the kidney with its fibrous capsule intact.

The patient is prepared as for abdominal operation by omission of food and fluids for at least eight hours, enema at night and morning, morphine ¼ grain and atropine $^{1}/_{150}$ grain when called to the operating room There are two usual surgical approaches to the kidney. Lumbar, in which case the patient is placed upon his side on the operating table, with kidney rest elevated, or using sandbags to present a taut lumbar region to the operator (Fig. 21-1). The skin is prepared with ether, followed by a thorough application of any of the recognized skin antiseptics. The lumbar approach to the kidney is extraperitoneal The second approach is transperitoneal, in which case the patient lies on his back, and a right or left, as the case may be, longitudinal incision is made just mesial to the outer edge of the rectus abdominal muscle. To secure better exposure this incision may be supplemented by a second low lateral or loin transverse incision which meets it at right angles. An anterior incision passes through skin, fat, fascia, muscle layers and anterior peritoneum, the intestines are packed off and the posterior peritoneum opened. In nephrectomies the renal pedicle should first be exposed and the blood vessels clamped and tied separately, using kidney, Ochsner, or large Kelly clamps. Next, free and deliver the kidney, then cut and ligate the ureter The peritoneal incisions are closed separately with No 1 plain catgut, and the abdominal wall is then closed in layers with No. 2 chrome catgut. One may, in secondary closures, use deknatel or linen stay sutures.

The lumbar incision is the one of choice in all except unusually large tumors. This approach to the kidney is facilitated greatly by the position of the patient, having the upper leg extended full length over the under-

for residual urine to prevent any refilling of the bladder by kidney output, which could be mistaken for a residual urine.

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twelfth rib downward we find the twelfth thoracic, the iliohypogastric and the ilioinguinal. To prevent postoperative muscle relaxation, allowing a bulge below the wound, it is well not to cut these nerve trunks. The lateral cutaneous and genitofemoral nerve follow in order below the ilioinguinal nerve and are usually below any lumbar incision for kidney exposure. Smaller nerve branches may be encountered in line of or across an incision, and occasionally must be cut. By locating the nerve trunk at the margin of the quadratus lumborum muscles, frequently the incision can be made to course along either above or below it, and so save considerable of its length, if not its terminal. We now have before us, exposed between retractors, retroperitoneal fat; posteriorly and deeper we find the renal or Gerota's fascia. With sponge dissection Gerota's fascia should be freed from the back muscle for a distance of 2 to 3 inches, retract this mass forward and open far down over the kidney. A finger inserted into this small opening will note that the fascia is unusually sharp-edged and resistant; it will also be noted that the fat now presented has a whitish or light yellow color. This is the perirenal fat as distinguished from the deeper yellow retroperitoneal fat, within which the ureter is found. The opening in Gerota's fascia is enlarged with the finger, the whitish fat grasped with clamps, preferably Pratt T clamps, which in the case of a mobile kidney allows sufficient traction to move it toward the operator. The fatty capsule is stripped by finger and gauze dissection; by scissor with a more difficult scar dissection. During enucleation of the kidney from within its fatty capsule, if any resistant band is palpated it should be visualized, as it may be an obstructing, aberrant vessel entering the kidney at an abnormal point. The pedicle is wiped down with gauze dissection, the ureter identified and separated from the renal vein and artery. Frequently an umbilical tape is placed under the ureter which permits lifting it away from the vascular pedicle when the latter is tied. It is always advisable to visualize these structures. In some instances, however, this is impossible. Occasionally when the renal vessels are either displaced or markedly adherent close to the vena cava it is well to clamp and cut the entire pedicle. It is advisable to clamp the vascular pedicle before clamping the ureter. The theory for this is that if the ureter is clamped first, infection or cancer cells from the kidney may be forced into the blood stream more readily while the completely blocked kidney is manipulated. Danger of injury to or of opening the peritoneum usually is not of great importance. It is, of course, well not to open the peritoneal cavity; however, if it should occur pack off and close with catgut sutures immediately.

If the vena cava, most unfortunately, is opened, it is preferable to close it with a large Kelly clamp placed parallel to the cava and over the rent. Leave the clamp on for four to six days, and then remove it in the operating room under anesthesia when completely prepared for any emergency. This is, in my opinion, the most satisfactory solution of such a very dangerous situation. Efforts may be made in certain instances to suture or ligate the large thin-walled vein. Occasionally when the renal vein enters the vena cava unusually high, or when the renal vein has been cut too close to the cava, a clamp may be left on for four days and then removed, making no effort whatever to tie the vein. If there is marked difficulty with

flexed leg. Also, the upper arm, raised upward to at least the level of the face and fastened to the edge of the table, assists in extending the loin. Elevation of the table need be sufficient only to draw the loin skin and muscles taut. The space for the oblique loin incision lies between the lower border of the twelfth rib and the crest of the ilium. Frequently this space is insufficient, in which case a twelfth or eleventh and twelfth rib resection is carried out. From the standpoint of shock and amount of surgery a large hydronephrotic kidney should be aspirated before freeing it.

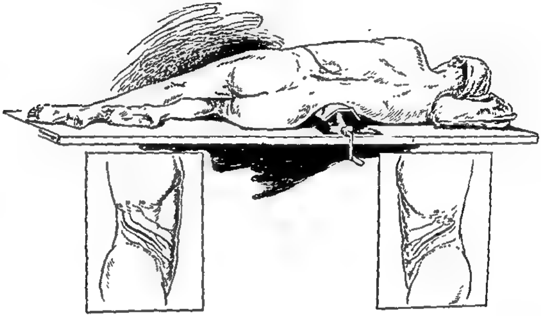

Fig 21-1 Diagrammatic, to show the kidney position, line of incision relative to the twelfth rib, the kidney rest elevator producing taut groin, which thereby spreads more readily, and gives freer opening for delivery of the kidney. Below left, hockeystick incision, and to the right, oblique kidney incision

There are various forms of incision. One, beginning at the costovertebral angle and extending obliquely to a point just anterior to the great muscles of the back, then turning anteriorly and hopefully following the course of the large nerve trunks, that is, not crossing these nerve trunks. This is often spoken of as a hockey stick incision. Two, a rather symmetrically curving to moderate S-shaped incision may begin at the same point and more or less follow the same course, except that the point or the angle where the oblique line of incision meets the anterior continuation is not as definite. This point, the lateral edge of the great (erector) muscle of the back, is important for it is at their meeting with the quadratus lumborum muscle that the large nerve trunks first are encountered. Either incision traverses the skin from the costovertebral angle as far anteriorly as seems necessary. The fat is then incised down to and then through the lumbodorsal fascia. The lattissimus dorsi muscle frequently is not recognized. The incision passes forward through fascia and the three abdominal muscles —external oblique, internal oblique, and the transversus abdominis. The surgeon has controlled bleeding and watched for the large nerve trunks; he now returns to the incision at the costovertebral angle often incising fibrous attachment to the twelfth rib to gain more space posteriorly. The large nerve trunks are most vulnerable near their emergence. From the

free it as far down as possible through the lumbar incision, cut and tie it. If, after nephrectomy, a small ureter with a stone in its lower third remains, and the ureteral *orifice is normal*, there has been no postoperative difficulty, in my experience, in following the ureter down between the thumb and forefinger, below the stone and below a point where the ureter can be cut and tied without enlarging the incision and more surgery, then evulsing it, more or less pinching off the ureter with the thumb and forefinger. The ureteral stub will contract and the small amount of urine in it will be readily cared for. A patent ureteral orifice, however, would make

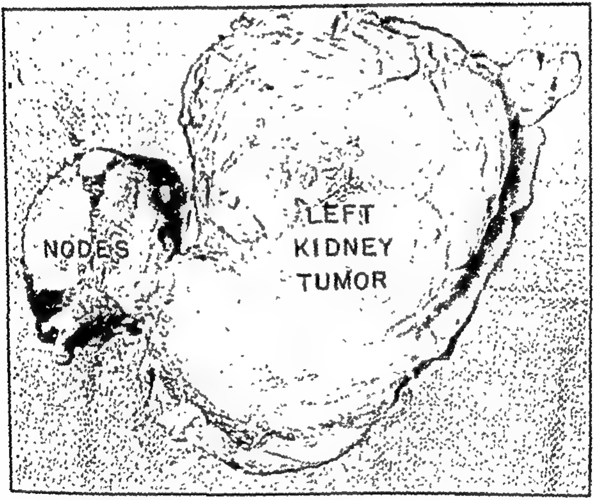

Fig 21-3 Kidney tumor with attached metastatic nodes removed en bloc Note that all surrounding fatty capsule is removed with the kidney (From Chute et al New England J Med, 241-951, 1949)

the ureteral stub in effect a bladder diverticulum and so tend to continue a urinary infection Such a ureter should be removed in its entirety and the bladder wall defect closed

Nephrectomy can be carried out if the tumor mass is exceedingly large, by removing the tumor bit by bit after the renal pedicle has been clamped. Also, the renal pedicle may be tied, then two or three days later at a second operation the mass removed bit by bit(8).

Dr. Richard Chute(39), of the Massachusetts General Hospital, Boston, in 1949 brought out the value of the *thoracoabdominal incision* in the removal of kidney tumors (Figs 21-2 and 21-3). The advantages, particularly

arterial bleeding, and the patient's condition does not warrant further search, again it is well to leave a clamp on the renal artery for four days, then remove it and make secondary closure of the wound.

Venous hemorrhage can be controlled by ligature or pack. If the kidney pedicle should get away from the surgeon, every effort should be made to regain and clamp it. However, it may, when necessary, be controlled by large wet packs. Such packing should not be done blindly, but with the wound widely exposed, using a large, wet, abdominal pack which is molded back and forth over the region of the vena cava and aorta, and pressed

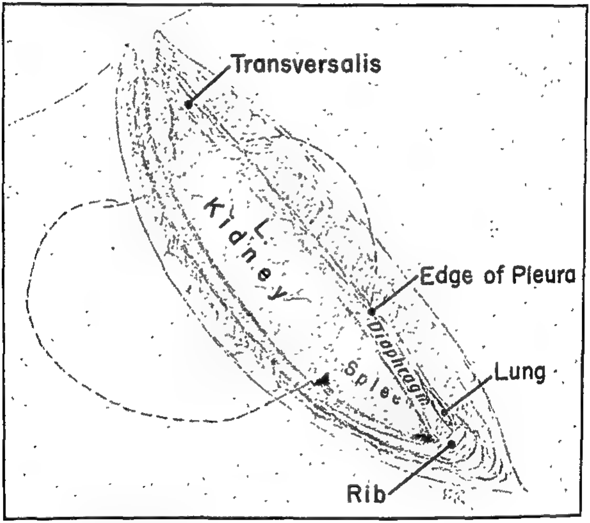

Fig 21-2 Drawing showing the peritoneal cavity widely opened (From Chute et al., New England J Med, 241 951, 1949)

down. Excessive amount of packing is of little avail and only obscures the results. After cutting the renal pedicle, the kidney will, in certain instances, hang by its ureter. Depending upon the ureteral pathology, the incision may be carried on down toward the region of the inguinal canal, with the peritoneum retracted mesially. By this method the ureter may be removed from the bladder itself, or even a cuff of bladder wall may be removed with the ureteral orifice. This procedure is advisable in papillary carcinoma of the kidney with implants along the course of the ureter. With a moderately dilated ureter, without a foreign body and no tumor present,

not be brought out at the upper point of the skin incision and thus be kinked over the edge of the quadratus lumborum and longitudinal back muscles to emerge with a sharp angulation near the costovertebral end point of the incision. The reason for this is that upon removal of the drain such an angular tract may provide unsatisfactory drainage. On the other hand, when any drain or catheter enters directly through the midincision down to the kidney space, it may be removed in four to six days without complication in most instances (Figs. 21-4 and 21-5).

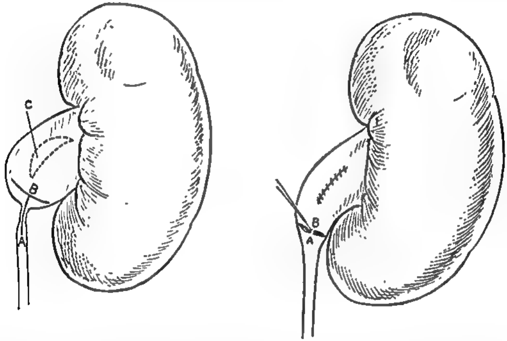

Fig 21-5. Plastic repair The left shows a dilated pelvis with constricted ureteropelvic junction, a Y, T or V incision of the Fenger or Foley type may be used In addition, a section of the dilated pelvis, C, has been excised. Reducing the size of the hydronephrotic sac assists to a better result in plastic surgery of the ureteropelvic junction, and gives a more rapidly emptying kidney pelvis We expect to have a widening of the ureteropelvic junction when A is approximated to B by suture When the ureter is severed an oblique ureteral incision should be made and, as C L. Demming points out, results are better—less frequent stricture when the ureter is implanted into the kidney pelvis for 1 to 2 cm A constricted ureteral pelvic junction can be widened by applying the Rammstedt pyloroplasty technic. D. M Davis first applied it to the ureter. It consists of dividing the ureteral wall through the point of constriction down to the mucosa This is best performed by introducing the "splint" ureteral catheter first Resection of dilated kidney pelvis should be included in this procedure Plastic procedures at the ureteropelvic junction should be plased facing the kidney, not on the anterior, posterior, or lateral surface of the ureteral pelvic junction The Rammstedt incision should be made upon the ureteral splint catheter Roy B Henline advises that the ureteral splinting catheter be left in for six weeks This is advisable in cases of marked constriction of the ureteropelvic junction I feel that the ureteral splint catheter should be used routinely wherever the ureter pelvic junction is mobilized, in these cases the ureteral splint catheter may be removed in two weeks.

Closure of Wound Closure may be done in many ways, with or without stay sutures, preferably with stay sutures and with interrupted 2-20 day catgut, with which usually three rows effect a layer-to-layer closure. One difficulty in closure which is frequently encountered is that the internal oblique muscle retracts quite badly after the kidney rest is lowered. Occasionally, in my opinion, it may be when the two edges of this muscle have not been satisfactorily approximated that we may have a postoperative bulge *of* the wound. A bulge *below* the wound is usually associated

in large tumors, are that the pedicle is approached directly, and that the mass delivers with greater ease and less handling. In a personal communication Dr. Chute states, "I usually take that rib which seems to lie over the upper-middle part of the kidney, but if there is any doubt, I would take the tenth rib rather than the eleventh, because there is no harm in being too high, as the wound can always be extended downward, but it is not good to be too low." Also, he is of the opinion that it is possibly better not to use silk in these cases, nor does he feel it necessary to inject or crush the phrenic nerve. He states, "I have been closing the pleural cavity around a catheter which has been brought out in a slanting manner through the various layers of the closure. When the skin has been closed, I have then had the anesthetist inflate the lung, have sucked on the catheter,

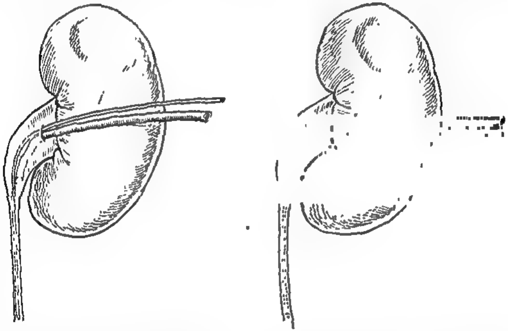

Fig 21-4. To the left a small No 10F. to No 12F., possibly No. 14F., soft red rubber catheter entering the pelvis and continuing down the ureter as a splint. *If desired*, a larger catheter, as shown, may be used for the *pyelostomy* drain. To the *right*, these tubes enter to these catheters a rubber tube or a Penrose drain nephrostomy incision. In many instances when the lint through an incision slightly larger, we find it ubber tube drain to the pelvis, however, it should be used with a nephrostomy A catheter may serve as a ureteral splint and pelvic drain.

and then have gradually pulled it out." A change from his original article is he has not been opening the peritoneal cavity so widely recently as in the early days. However, he usually makes a small opening in it, which he finds of great value in helping establish the cleavage plane between the peritoneum and the intact Gerota's capsule. "It is important to develop this cleavage plane between these two structures and to deepen it down to the pedicle and the great vessels." Dealing with the pedicle approached in this manner by retracting the peritoneum and its contents medially, is very important in Dr. Chute's opinion. He feels that when the pedicle has been secured the operation is very well in hand.

Drainage Following Nephrectomy. It is important that the drain, such as a cigarette tube or Penrose, should emerge midincision. It should

kidney, or it may be freed more completely, wadded into one mass by catgut sutures, sewed to the lower pole of the kidney capsule and to the back muscles. Whenever infection is associated with nephroptosis, it is unwise to use silk. Otherwise, three braided silk Brödel sutures placed in a triangular interlocking manner, one at the top, middle and bottom of the kidney and sewed to the back muscles, not looped over the twelfth rib, which might cause pain, will hold the kidney in position indefinitely. When rotation is present placing of these sutures may make a very definite attempt to correct the rotation. When infection is present the sutures should be of number 2-20 day catgut, and suspension with the fatty capsule as outlined used in addition. Catgut sutures do not assure permanency of fixation; further to aid in this regard, the fibrous capsule of the kidney may be incised with many linear crisscross incisions, so that its fibrous adherence may be more definite to the back muscles; or a strip of the fibrous kidney capsule may be turned down and sutured to the back muscle.

Carbuncle of the Kidney and Perinephritic Abscess. Carbuncle of the kidney is a localized infection within the kidney substance. There may be communicating abscesses or a large solitary abscess. When the abscesses are multiple they may be connected by small, winding fibrous tracts. Symptoms are usually confusing; a definite kidney area pain and indefinite tenderness are usually present in the costovertebral angle. The white blood count and temperature will be moderately increased, urine often not infected, pyelograms normal, and kidney function quite normal, yet with persistent pain in the kidney region. Sulfa drugs and antibiotics may be successful in effecting relief. When the inflammatory cavities are thick walled failure of chemotherapy is quite inevitable. The abscess may rupture and the doubtful diagnosis suddenly become quite clear as a perinephritic abscess forms. Excision of the infected areas, together with penicillin or sulfa drugs, will frequently give a satisfactory result. Nephrectomy in very rare instances is necessary; in others the abscess may be packed with penicillin gauze and antibiotics given by mouth or by hypodermic.

Perinephritic abscess requires surgical drainage only, together with chemotherapy, unless the history suggests a complicating renal carbuncle.

Calyxectomy and Heminephrectomy. Heminephrectomy in kidneys with long infundibula to superior or inferior major calyces or with bifid pelves is indicated quite frequently when the upper or lower half is damaged by stone, pyelectasis and infection. With both kidneys involved save all the renal tissue possible!

Calyxectomy should be done when a calyx is markedly dilated and scarred and its infundibulum relatively small and therefore probably incapable of returning to normal function. In such instances complicating a kidney stone, calyxectomy (Fig. 21-6) reduces the recurrence of stone and lessens the chance for a continued kidney infection.

Aplastic kidneys or kidneys with deficient blood supply, sclerotic or not, are removed in patients with hypertension, and occasionally for the relief of infection or pain Ectopic kidneys usually are not removed; however it is possible for them to cause pressure or passive congestion pain and, due to their ectopic position, they may not drain well and therefore may be associated with stone or chronic infection. Only such ectopic

with some sensory skin changes and, therefore, due to damage to the 12D–iliohypogastric or ilioinguinal nerve. If stay sutures, such as 28 gauge stainless steel or silver wire, deknatel, linen, or silk are to be used, it is very well to put them in before the kidney rest is lowered or the sandbags removed from underneath the lower loin. They are tied after muscle closure. After the kidney rest is lowered, it is easy to approximate each of the abdominal muscle and fascia layers, the fat layer is then closed either separately or completely by one or two rows of interrupted or running 1–plain or chromic catgut sutures. Difficulty in skin approximation is encountered particularly in very fat people when the incision is in line with or broken by a deep skin fold. This can be prevented, in closing a very thick fat layer, by approximating the skin edges with a subcutaneous suture before they are sewed with interrupted, running silk or catgut sutures. The wound is dressed most satisfactorily without too much gauze. P.R.N. ties are most desirable. They are made by crossing an 8-inch length of umbilical tape into and near the end of a 2-inch adhesive strip, then folding the adhesive back upon itself and over the umbilical tape, thus leaving two free ends of the umbilical tape. Nine or ten inches of this 2-inch adhesive strip is then fixed to the body, so that in all four such ties approximate from opposite direction over the dressing.

Nephropexy. Nephroptosis in itself usually is of little importance. We must determine whether or not the fall of a kidney causes pain by tugging upon its vascular pedicle, by pressure upon neighboring structures, or (which is far more important than these) by interfering with urinary drainage. Interference with the flow of urine, therefore urinary back pressure, usually requires that the ureter, following down after the ptosed or displaced kidney, meets with a point of scar fixation or falls over an aberrant blood vessel, causing a ureteral kink. Ureteral kinks are not *primary* pathologic lesions in the vast majority of instances, and should not be diagnosed as such. Frequently, a definite ureteral kink in one pyeloureterogram will not show in subsequent pyelograms, taken 5 and 15 minutes later, or the method and apparatus of T. D. Moore(9) may be used. This point is also frequently very well brought out by taking the pyeloureterogram first with the patient flat, head down slightly, then with the patient erect on the x-ray table. This procedure is necessary to establish the degree of fall or nephroptosis. However, the degree of fall in itself is not important, it depends whether or not the ureter is involved in the fall in a manner to obstruct the flow of urine. The pain that we look for usually is a Dietl's crisis *type* pain It occurs because the ureteral obstruction is intermittent, and therefore pressure anesthesia is not established as it is in a large hydronephrosis. A dull, heavy pain in the kidney region anteriorly or posteriorly may be due to a passive congestion associated with a malposition of the kidney, or to a well established hydronephrosis.

Nephropexy may be accomplished through a right oblique loin incision. The kidney is delivered, mobilized completely and the pedicle also freely mobilized. The fatty capsule must be stripped off; it may be used as an accessory support in the kidney suspension in either of two ways. One, leaving its attachment anteriorly near the hilus and sewing it high to the quadratus lumborum muscle, thereby making a sling for the

fection, the entire ureteral function. However, today with intravenous pylelograms these stones are now either removed by open surgery or by cystoscopic methods. In general, cystoscopic methods are in less favor as time goes on. Severe accidents occur, repetition of the attempt is often necessary, and failures are frequent.

Tumors of the ureter are usually malignant and should be considered to be malignant when diagnosed, and that would require, therefore, excision of the entire ureter and removal of the kidney. Benign fibroma of the ureter does occur but such a pathologic diagnosis by frozen section, at the time of surgery, may be insufficient for a decision not to remove the entire kidney and ureter. However, when definitely indicated, a benign uretral fibroma or stricture may be excised, with closure of the ureter over a catheter splint. This should result in normal flow of urine through the operated area.

The Foley(10) operation, described in 1935, is admirable for uncomplicated lumbar ureteral stones which are too large for cystoscopic ureteral manipulation. Foley describes it as, "a 10 to 12 cm. incision, extending in a vertical oblique direction from the middle of the twelfth rib toward the anterior superior spine of the ilium. Division of the skin and subcutaneous fat exposes the posterior edge of the external and internal oblique muscles and the anterior edge of the latissimus dorsi muscle, midway between the twelfth rib and the iliac crest." The muscles are separated, not cut, and the lumbodorsal fascia is exposed. Foley then continues:

"Lumbodorsal fascia is now split parallel to its fibers, with exposure of the posterior layer of the perirenal fascia. This fascia and anterior layer of the perirenal fascia form an envelope completely enclosing the perirenal periureteral fat. Instead of immediately opening this fascia to approach the ureter through its surrounding fat as is usually done, the dissection takes advantage of the clean cleavage plane between the posterior layer of the perirenal fascia and the muscles on which it lies.

"By blunt resection this cleavage plane is opened by gently stripping the fascia away from the muscles. This stripping continues on to the vertebral bodies. With the perirenal fascia and the contained fat elevated and held away from the muscle by a lever retractor, the ureter will be seen a pale, ribbon-like streak running longitudinally, 3 or 4 cm. lateral to the vertebral bodies and immediately under the fascia."

The advantages of this operation are small operative wound and less shock, while the disadvantages are that the incision is small and limits exposure, and that the depth of the wound is difficult to see, even with a specially directed light However, it has very definite advantages, and Dees(28) suggests that it be used when indicated for surgery of the ureter: 1, in pregnancy, tuberculosis; 2, for preliminary nephrostomy; 3, for drainage of perinephritic abscess, 4, for biopsy of kidney tumor; 5, for exploration of retroperitoneal space, and 6, for bilateral ureteral lithotomy. There are other surgical instances in which it will have very valuable application, but we must keep in mind that surgery for stone must include correction of faulty drainage of urine or we invite a recurrence of stone.

In 1951 Dr. David M Davis(40), of the Jefferson Medical College, Philadelphia, brought out his very valuable work "Intubated Ureterotomy."

kidneys then should be removed, and only when the opposite kidney has sufficient function to support normal life.

A third kidney is extremely rare. Such instances commonly are confused with a single kidney having two ureters and two pelves. These duplications are classified as bifid pelves. Their ureters may join anywhere from the hilus of the kidney to the ureteral orifice or there may be separate ureteral orifices, that is, entire reduplication. Such kidneys usually serve the person for a lifetime without trouble; however, pathologic changes, particularly stone and infection, are more common with them than with perfectly normal kidneys. The difficulty lies in interference of the flow of urine, which invites infection. The intravenous pyelogram is valuable in diagnosing these conditions, as it locates the kidney and shows its substances (size and shape), and function in its ability to excrete iodine.

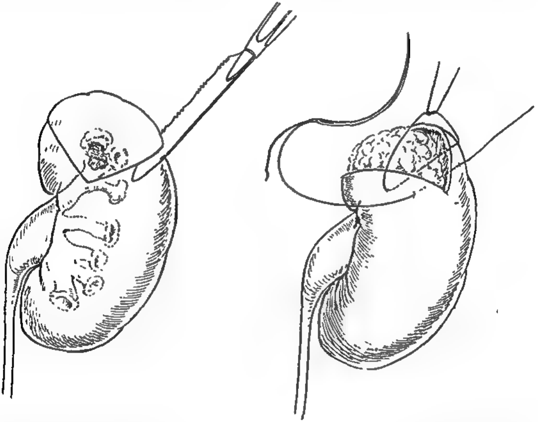

Fig. 21-6 Calyxectomy. After excision of the calyx a small bit of fat, or muscle, may or may not be placed in the opening and sutured in as shown on the right hand drawing. *Closure* should be with 2 plain catgut.

Strictures and obstructions of the lower ureter are more amenable to dilatation by operative cystoscopic methods than those of the upper ureter. Hydronephrosis associated with these strictures in the upper pole are secondary and not primary disease. Infection associated with a stagnant urine of a hydronephrosis is an all-important subject. Many methods have been used for removing stones in the low ureters. We should give consideration first to the type of stone—if it is irregular in its outline usually urine will flow around it and dilatation of the ureter above it will not occur as rapidly. A stone perfectly smooth in outline becomes a block before a considerable period of time, and can destroy by back pressure, plus in-

The sum and substance of the work that has been of great benefit to kidney surgery is that if one incises the constricted area of the ureter over a tube that has been previously placed in the ureter, and if this incision is left wide open and splinted by a ureteral tube, it will heal without stric-

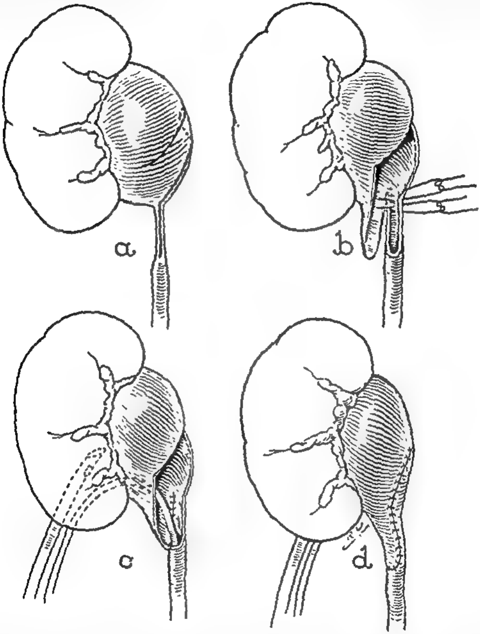

Fig 21-8 Technic of a new operation, by Dr. Ormond S Culp and Dr James H. DeWeerd (41) of the Mayo Clinic, which promises a great improvement in treating certain ureteropelvic obstructions. a, location of incisions to create the pelvic flap and to open the constricted segment of ureter. b, anatomic relationship of flaps and open ureter, adjacent edges joined by sutures of 000 chromic catgut c, nephrostomy tube and ureteral splint inserted through a lower calyx after one edge of flap has been attached to the split ureter d, flap sutured to other edge of split ureter over the splint, and defect in pelvis closed. (From Culp, O S. J. Urol., in press.)

ture, or with a perfectly normal size ureter in a great percentage of cases (Fig. 21-7). There are a few failures He feels splinting tubes of polethylene, size 12 or 14, are somewhat too stiff. The splinting tube may be introduced through the renal pelvis abdominally or by way of the ureteral orifice. The ureter should be properly calibrated in all cases. The poly-

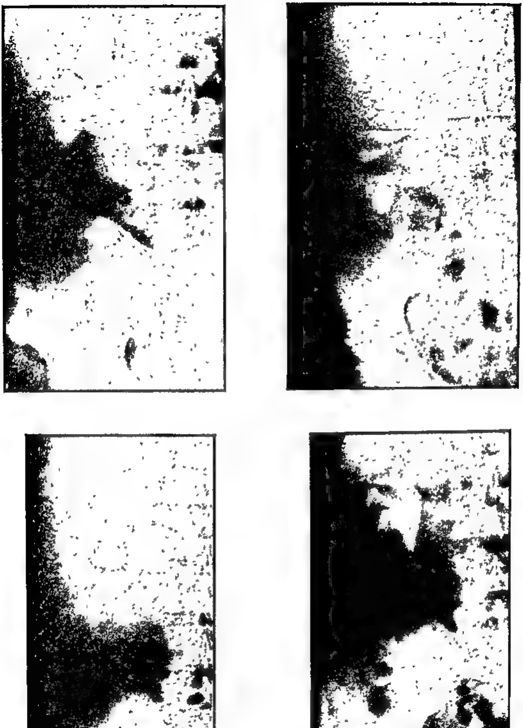

Fig. 21-7. Top left, retrograde pyelogram showing a large hydronephrosis in a male patient Top right, erect picture showing fluid level in dilated calyces. Bottom left, intravenous urogram before operation. Bottom right, intravenous urogram after intubated ureterotomy. (Courtesy Dr. David M. Davis)

traction the urinary stream starts rather weakly at first, to gain momentum midflow, *and then to decrease in force as the bladder approaches emptiness*. When urination ceases, the contraction of the perineal muscles lessens, as does that of the trigonal muscle; next, the internal orifice rises again to its normal position. At the time that the internal orifice rises the bladder wall definitely returns to its passive tone and adaptability to filling. The terminal jets of urine from the bladder that is emptied imperfectly are brought about by alternately raising and lowering the internal orifice by means of intermittent voluntary contractions of the perineal muscles. It is in effect pumping urine out from a collapsing bladder. In periods of *great stress or threatened incontinence of urgency the perineum is elevated* tightly, even the legs may be crossed, so that the adductor muscles may serve to hold the anterior perineum, and so the bladder internal orifice, higher. One may see this in a child who runs cross-legged to keep from becoming incontinent.

This physiologic explanation gives us a method of interpreting types of retention or incontinence of urine, which can be of great value in surgery involving the internal orifice of the bladder and the posterior urethra. It is necessary for an understanding of dysuria due to disease of the central nervous system, and of symptoms preoperatively and postoperatively, particularly in prostatic surgery.

Neurogenic Bladder. Neurogenic bladder is a neuromuscular dysfunction of the urinary bladder. In a great majority of cases the abnormal neurogenic factor primarily influences the voluntary phase of micturition, with secondary bladder wall chances following; as previously pointed out the involuntary phase (strength and sensitivity) of bladder contraction normally follows the primary voluntary muscle movement. We may classify neurogenic bladders as atonic or spastic, and while these terms suggestively refer to the bladder itself, they should also refer to the state of the voluntary urinary musculature—the voluntary muscle sphincter complex.

An atonic neurogenic bladder is associated with a break on the sensory side of the voluntary reflex arc, which reduces tone and sensation of the posterior urethra. As involuntary bladder wall contraction is directly brought about by *the sensory status of the posterior urethra, contraction* of that viscus will be reduced in force when the posterior urethra is anesthetic to any degree. In such instances, in degree, we may find occasional leakage of urine to continuous dribbling, occurring without a definite *sense* of a desire to void, as the bladder wall decompensates.

A second general type of neurogenic bladder, those with a spastic voluntary sphincter, will do exactly the opposite. Such a sphincter obstructs the bladder; a thickening compensation of the bladder wall by actual hypertrophy and by bladder wall contraction, in an effort to overcome this obstruction, is expected to occur. Irritation to the upper motor neurones in the spinal cord will produce this spastic voluntary sphincter mechanism. Recall that voluntary control of the bladder orifice is from point of strength, the anterior perineal muscles moving up and down from their functional attachment to the urogenital trigone; for this reason palpation of the anal sphincter will give an index as to the status of the voluntary sphincter control of the bladder, as well as of the voluntary anal sphincter.

vinyl tube may induce an allergy reaction. He states, "rubber continues to give good results in spite of everything." Dr. Davis drains the kidney separately. His results are satisfactory in about 90 per cent of all cases, and when they are not satisfactory it is usually due to recurrence of stone or stricture, and in these cases subsequent nephrectomy in a few instances may be indicated.

Dr. Davis leaves the intubating tube in for various lengths of time. Our clinic at Barnes Hospital usually chooses two, or possibly three, weeks. Others up to six weeks. Individual cases influence this period of time. Not only is the intubating ureterotomy of great value in instances of upper ureteral stricture (Fig. 21-8), but in my opinion has brought out that great value can be realized by splinting a great many ureters where there is no ureteral obstruction. A No. 10, possibly No. 12, red rubber urethral catheter in these instances, brought down from the pelvis through the ureteropelvic junction and through the upper portion of the ureter, when that kidney is postoperatively going to remain in a normal position, will assure normal ureteral dilation, and one may expect more rapid closure of the associated pyelostomy or nephrostomy drainage wound after its removal, in these instances 10 to 14 days later. These points are, should we say, valuable side effects of Dr. Davis' work. In his early experimental work he actually intubated upper ureteral strictures—the splinting catheter now intubates the ureter.

THE BLADDER AND MICTURITION

Function. The bladder is made up of interwoven bundles of smooth muscle which, in various areas, can contract and dilate simultaneously, thus maintaining a passive intracystic pressure as the bladder fills to a point of stretch stimulation. This physiology explains how the individual is able to carry urine in the bladder without sensation, even though there is a sudden direct blow or a sudden jar to the entire body.

The bladder fills to a point of slight suprapubic discomfort. Such discomfort may be transmitted to the urethra if the pressure or contraction of the bladder wall is sufficient to stimulate the internal orifice and proximal posterior urethra. If this first sensation of bladder filling is not obeyed, in the normally elastic bladder further dilatation for the accommodation of more urine will occur. When, however, urination becomes necessary we realize it to be voluntary-involuntary reflex. The individual repairs to the toilet and voluntarily lowers the internal orifice of the bladder by relaxing the anterior perineum. This lowering of the anterior perineum seems to be accomplished by a lengthening of the anterior perineal group of muscles. This first and voluntary movement lowers the internal orifice of the bladder, thereby putting a stretch upon the trigonal muscle. This stretch stimulates the trigonal muscle to contraction, a stretch reflex, which widens and smooths down the floor of the internal orifice. In transurethral surgery we often resect the trigonal muscle without interfering with bladder function. Therefore, it is the perineal muscles which actually open the internal orifice. Urine now flows from the bladder into the prostatic urethra, or into the posterior urethra of the female, thereby stimulating an involuntary bladder wall contraction(5). With this involuntary bladder wall con-

and is an index of the muscle state of that wall. The catheterization contracted, "compensated," the bladder wall, but eventually the prostatic obstruction will win and the bladder again will become overdistended. The influence of cerebral inhibition is upon the perineal muscles—the voluntary muscles which initiate urination.

Pressure Anesthesia. We also see transient desensitization within the urinary tract not primarily neurogenic, but due to back pressure upon the nerve terminals within the ureter, pelvis, or bladder and possibly upon the posterior urethra proximal to the bladder orifice. Such changes should be called sensory adaptation, transient, physiologic, or *pressure anesthesia.* In other words a prolonged increased pressure upon the sensory terminals of the areas mentioned can decrease sensitivity and so reduce reflex motor function that more urine will be passively accommodated, or micturition will not be normally initiated.

Residual Urine. We see this sensory adaptation in the entire urinary tract in a painless large hydronephrosis; also it is basic in producing *bladder residual urine.* For example an individual at a first examination may have a 1,000 ml. residual urine; after the bladder is emptied by catheter we are immediately able to replace only 500 ml., 600 ml. or so of water. In other words in the short space of time between emptying, releasing the back pressure from the sensory terminals, and refilling the bladder, we have in degree allowed normal sensation to return. We have also contracted a hypertrophic bladder wall. The two factors account for the sudden decrease in bladder capacity! This functional change after emptying can also be applied to ureteral catheterization.

The Cystometer. The cystometer(7) was devised in 1927 to measure not alone the bladder capacity, certainly *not alone bladder pressure,* but to reproduce as a diagnostic clinical test all of the functions of the bladder and posterior urethra. Such a test can be correctly accomplished only with a continuous, or near continuous, flow instrument which measures pressure and capacity and ability to retain urine simultaneously as water flows into the bladder. The cystometer should register a line between two ordinates of pressure and capacity; bladder sensitivity and holding power of the sphincter mechanism should be noted upon this line (Fig. 21-9). The reason for these statements is that the bladder is an organ of immediate accommodation. In a cystometrogram we note sensation, degrees of capacity sensation upon the pressure line. The angle with the posterior urethra—rigidly upward or weakly falling downward—in which a rigid catheter is held, determines the spasticity or atonicity of the perineum; the important part of the voluntary sphincter mechanism. A tabetic bladder will in a cystometrogram show a flat curve with delayed sensation, while the irritable bladder, or cystitis type of cystometrogram whether inherent in the nervous system or due to an inflamed mucous membrane, will exhibit an increased sensory and abrupt emptying or motor response. Two fillings of the bladder at the same sitting show the response of the bladder wall to stretch stimulation of the first filling—another index of bladder muscle strength and irritability; in an irritable or overly strong bladder the second cystometrogram will show less capacity, stronger contraction and greater irritability—the opposite being found in an atonic bladder.

In the spastic type a residual urine occurs from outlet block—in the atonic from a decompensated (weak) bladder musculature.

TREATMENT. The objective indication in treatment of neurogenic bladders is to remove permanently the residual urine and to reduce bladder and sphincter obstruction. In the well established *spastic* voluntary sphincter type this means medical treatment and a transurethral resection of the internal bladder orifice. We may allow an overflow incontinence to develop until a high nonprotein nitrogen or sepsis require interference, as hopefully in certain cases an automatic bladder without infection or with a small residual urine may be the final situation. On the other hand the atonic bladder with its atonic urethra may frequently be catheterized with impunity. No rule can be given. Each neurogenic bladder is a complex individual instance of altered physiology.

Regarding the congenital neurogenic bladder with spina bifida McCarroll(6) has suggested a trial method of treatment. Incontinence often is a disagreeable symptom; it may be due to expulsion from a small spastic bladder or to overflow of an overfilled bladder. Either form of incontinence may be treated logically. The contracted bladder back of an abnormal sphincter mechanism may be overdistended by hydraulic pressure, or the outlet may be dilated or resected in the case with a blocked bladder by neurogenic spasm of the voluntary outlet. These rules for treatment in neurogenic dysfunctions should be applied whenever the neurogenic changes are permanent or have persisted for some time and the possible value of transurethral resection has been weighed. If catheterization or a three day retention catheter increases the ability to void, then, based upon the suggestion of Nesbit, resection of the bladder neck may be indicated. The chance of incontinence however must be considered in each case.

The influence of neurogenic bladder dysfunction may be exerted upon the upper urinary tract. To protect kidney function one rule is inflexible—the uninfected bladder which is blocked by a spasm of the voluntary mechanism, which is usually caused by the irritation of the upper long motor neuron, must not be unnecessarily infected unless satisfactory surgical drainage is immediately offered to that bladder. In other words such a bladder should not be subjected to catheterization and transurethral resection unless for some unusual reason it is absolutely necessary. Cystostomy may be performed whenever it seems worth the chance on the probability of a short-lasting spasm of the voluntary sphincter mechanism.

The cerebrum exerts an inhibitory influence upon the involuntary bladder wall. Its control is invariable upon the normal bladder wall but variable upon the atonic or hypertonic bladder wall This is seen for instance in a man with a prostatic obstruction which has brought about over the years a marked thickening or hypertrophy of the bladder wall If for some reason the senorium in this patient is lost there may at first be overdistention of his bladder, and dribbling may ensue immediately. If when this bladder is overdistended, however, the patient is catheterized, we will note for the first day a dribbling of urine, the next day a voiding of small amounts, and the next day incontinence of small, though larger, amounts. This points to a progressive increase in the capacity of this bladder wall

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Pressure Anesthesia. We also see transient desensitization within the urinary tract not primarily neurogenic, but due to back pressure upon the nerve terminals within the ureter, pelvis, or bladder and possibly upon the posterior urethra proximal to the bladder orifice. Such changes should be called sensory adaptation, transient, physiologic, or *pressure anesthesia.* In other words a prolonged increased pressure upon the sensory terminals of the areas mentioned can decrease sensitivity and so reduce reflex motor function that more urine will be passively accommodated, or micturition will not be normally initiated.

Residual Urine. We see this sensory adaptation in the entire urinary tract in a painless large hydronephrosis, also it is basic in producing *bladder residual urine.* For example an individual at a first examination may have a 1,000 ml. residual urine; after the bladder is emptied by catheter we are immediately able to replace only 500 ml., 600 ml. or so of water. In other words in the short space of time between emptying, releasing the back pressure from the sensory terminals, and refilling the bladder, we have in degree allowed normal sensation to return. We have also contracted a hypertrophic bladder wall. The two factors account for the sudden decrease in bladder capacity! This functional change after emptying can also be applied to ureteral catheterization

The Cystometer. The cystometer(7) was devised in 1927 to measure not alone the bladder capacity, certainly *not alone bladder pressure,* but to reproduce as a diagnostic clinical test all of the functions of the bladder and posterior urethra. Such a test can be correctly accomplished only with a continuous, or near continuous, flow instrument which measures pressure and capacity and ability to retain urine simultaneously as water flows into the bladder. The cystometer should register a line between two ordinates of pressure and capacity, bladder sensitivity and holding power of the sphincter mechanism should be noted upon this line (Fig. 21-9). The reason for these statements is that the bladder is an organ of immediate accommodation. In a cystometrogram we note sensation, degrees of capacity sensation upon the pressure line The angle with the posterior urethra—rigidly upward or weakly falling downward—in which a rigid catheter is held, determines the spasticity or atonicity of the perineum, the important part of the voluntary sphincter mechanism. A tabetic bladder will in a cystometrogram show a flat curve with delayed sensation, while the irritable bladder, or cystitis type of cystometrogram whether inherent in the nervous system or due to an inflamed mucous membrane, will exhibit an increased sensory and abrupt emptying or motor response. Two fillings of the bladder at the same sitting show the response of the bladder wall to stretch stimulation of the first filling—another index of bladder muscle strength and irritability, in an irritable or overly strong bladder the second cystometrogram will show less capacity, stronger contraction and greater irritability—the opposite being found in an atonic bladder.

Cystometrograms are graphs of individual bladder reaction to filling and should graph that person's symptoms and so give reason for treatment. They are not diagnostic tracings as are the electrocardiograms. The diagnosis is made with the cystometrograms, together with all other data and diagnostic methods.

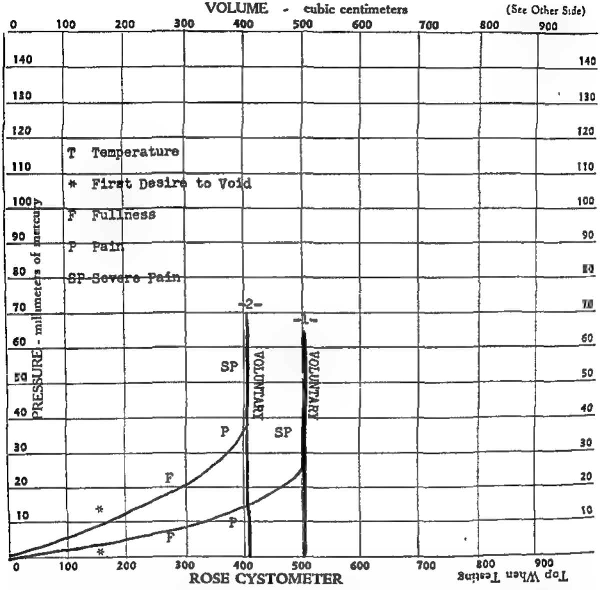

Fig 21-9 Normal cystometrogram representing a type of normal, fair capacity, gradual increase in pressure with the various sensations properly placed, also normal urinary control, as neither voluntary nor involuntary leakage occurred Relationship between sensory and motor responses to capacity and control are thus graphed for subsequent reference

Urinary Retention. Three types of urinary retention are of surgical interest. 1, *postoperative retention,* in which bladder sensation, the desire to void is present, particularly before pressure anesthesia due to an overfilled bladder lessens bladder sensation. The cystometrogram shows low intracystic pressure with normal bladder sensation. The explanation is that the patient, for fear of wound pain, is unable voluntarily to initiate urination, and the bladder overdistends! This patient may in most uncomplicated cases be catheterized as necessary.

2. *Retention of urine following combined abdominal perineal surgery for carcinoma of the rectum*—the cystometrogram is not notably altered from normal. Cystoscopically the removal of the rectum allows the bladder base and posterior urethra to sag, a *male cystourethrocele;* the internal orifice between the posterior urethra and bladder base is relatively higher than normal due to the fall of the bladder base behind, and the posterior urethra in front of it. If there is added obstruction at the internal orifice, by a prostate or by a contracted urethral orifice in the female, then urinary obstruction is increased and may be corrected by correcting such an obstruction with either transurethral or open surgery; in females, perineal repair often eradicates urinary retention.

3. *Postpartum retention* is exactly the opposite cystometrically of postoperative retention—such a bladder shows normal involuntary pressure and no sensation; trauma of delivery or an episiotomy may, however, give the young mother a postoperative type of retention, i.e., low pressure and normal bladder sensation. Intermittent catheterization in a postpartum (high intracystic pressure) leads to a diffusion of bladder infection, often to dilated ureters and pelves. *Retention* catheters in uncomplicated postpartum urinary retention should be used until bladder sensation becomes normal. The temporary decrease in sensation is due to pressure of delivery or to the unusual intrapelvic pressure during the last days of pregnancy.

Cystoscopic Examination. The Brown-Buerger cystoscope and the McCarthy cystourethroscope are most widely used at the present time. The Brown-Buerger cystoscope consists of an outer sheath of varying sizes, from a No. 10 to a No. 26 French. A space about the obturator allows water to flow into the bladder by way of a petcock located near the ocular. There is an outflow petcock on the opposite side. Two obturators are usually furnished, one for viewing, which gives a larger field, and the other to serve as a ureteral catheter carrier. Ureteral catheters vary in sizes, from No. 4 to No. 8 French. The No. 5 and No. 6 French are usually used. When larger sizes are used they are accommodated by operating type catheter carrier lens systems, which carry one rather than two ureteral catheters. Magnification by these instruments varies from four times normal size at 1 inch away from the lens, to normal size when the lens is brought immediately to the surface viewed. The Jos. F. McCarthy cystourethroscope is made of metal; also his foroblique lens made possible the Stern-McCarthy (bakelite) resectoscope used for transurethral section of the prostate. The bakelite resectoscope was devised in 1926 by Stern and improved in 1931 by McCarthy. The Stern-McCarthy resectoscope is the instrument of choice in the hands of many for protatic resection. The Braasch-Bumpus-Thompson resectoscope, in use today for transurethral resection, is cold cutting and is highly satisfactory in trained hands.

The Mededith Campbell and the McCarthy miniature cystoscopes, urethroscopes, and resectoscopes are most widely used in infant urology.

The No. 16 F. Brown-Buerger cystoscope can be used as both cystoscope and urethroscope in many cases. An outline for the diagnostic necessity and use of the cystoscope and urethroscope has been given in the Method of Diagnosis outline.

The lens system used in transurethral instruments, devised chiefly

through the genius of Rheinhold Wappler and carried on by his successor in The American Cystoscope Mfg. Co., has greatly diminished the necessity for open bladder and prostate and urethral surgery, and also shortens the time of operation and of hospitalization and with improved results. Many tumors of the bladder can now be resected or coagulated cystoscopically; biopsies for determination of degrees of malignancies can be obtained, stones and many foreign bodies in the bladder can be crushed with or without visualization, using a litholotrite or a Young rongeur cystoscope. Hyperplastic areas of the posterior urethra may be removed, as well as obstructing factors such as congenital valves, a large verumontanum, and different forms of prostatic obstruction. Scissors of the Neil Moore electrode may be used to enlarge ureteral orifices. Foreign bodies may be removed with varying forms of rangeur instruments. From the ureteral dilators of Bransford Lewis to the inflatable ureteral bulb catheter of Doudmashkin and the Johnston and Churchill baskets and Balkus loop, ureteral stones have become more easily removed by cystoscopic means, particularly when they are low in the ureter and not complicating kidney function. The Stern-McCarthy resectoscope, while primarily for prostatic resection, is often most valuable for resection of bladder tumors which may be treated later with radon implant or cystoscopic diathermy and often with deep x-ray therapy.

Bladder Surgery. Surgery of the bladder may be classified as either open or closed. Open surgery is necessary for infiltrating and some large pedunculated tumors; for very large or hard stones; malformations, congenital or acquired, and often, though not always, for the effects of trauma, either blast, puncture by missile or other foreign body from without, or by pelvic bone from within, depending upon the degree of rupture and whether or not a retention ureteral catheter will furnish adequate drainage. Overdistention rupture of the bladder is very rare; when it does occur, it would seem that some one area must have reached the limit of its elasticity to a greater extent than the entire bladder wall. This would point to a thinning cellule or diverticulum with scar, or to tumor.

Closed Surgery. Closed surgery of the bladder has been perfected by Brown, Buerger, Bumpus, Thompson, H. H. Young, Jos. F. McCarthy, and many others. With electricity we have desiccating, coagulating and cutting currents, using active electrodes, cutting loops, points, scissors, and the ureteral orifice incisor of Neil Moore. Nonelectric instruments are more varied, we have scissors, crushing instruments, curets, rongeur cystoscopes and forceps, baskets and screws. By such means the necessity for open surgery of the bladder for stone and tumors in particular has been decreased more and more, year after year.

Open Surgery. In open surgery of the bladder its anatomy and physiology must be kept in mind. One point for consideration is that when open it contracts, and that in contraction its wall is much thicker than when in distention. A tumor, therefore, viewed cystoscopically, may appear in the distended bladder to have a bladder wall infiltration limit, let us say, 1 cm. from the tumor edge This same tumor, however, in the opened and contracted bladder wall, may not appear to extend into the normal muscle; more bladder wall will be excised in a contracted bladder

when cutting around the tumor 1 cm. from its margin, than would be excised in the same filled, stretched, bladder wall when using diathermy or planting radon seeds cystoscopically 1 cm. from the same marginal tumor line. Therefore, when planting radon seeds through the cystoscope, a wider area around the tumor must be covered as an early invasion may be a millimeter distant from the main tumor mass in a contracted bladder, but one centimeter distant in a distended bladder.

In view of the change in the size and in the resistance the stretch of the bladder wall when it is opened, a caudal, sacral or spinal anesthetic, is frequently a great help in rendering the open bladder more amenable to stretch, and therefore to surgical exposure. Such anesthetic may be used for this purpose alone, and may be supplemented by a general anesthesia. Twenty milliliters of 2 per cent novocain as a caudal anesthesia will produce bladder wall relaxation for an hour, sometimes longer. A spinal, sacral, or parasacral anesthetic, will produce longer effect. A cystometrogram of a bladdder after caudal anesthesia shows marked relaxation and definite anesthesia.

Open surgery of the urinary bladder is usually followed by drainage, a cystostomy. If a cystostomy is done after closure it is wise to drain down to the bladder wall, or use a retention urethral catheter. Cystectomy with uretero-intestinal anastomosis is accepted today as the method of choice in infiltrating malignancies of the bladder. Higgins'(27) results have given impetus to the operation. It should be performed only in those which show deep infiltration though small, or in larger or widely spread lowgrade malignancies. It is preceded by implantation of the ureters into the sigmoid by the Coffey operation or a modification of the Coffey operation.* The ureters also may be implanted into the skin, loin and an ambulatory urinal worn. Heckel(11) has recently improved this method of drainage by infolding the skin with cross incisions near the actual ureteral skin junction. Dilated ureters are best brought out to the skin rather than implanted into the sigmoid.

Interstitial Cystitis. An interstitial cystitis (Hunner ulcer(19) or elusive ulcer) may be associated with an obstruction within the pericystic lymphatic system. Cystoscopically in some regards this lesion appears to be a perivascular lymphangitis. Cystoscopically we see a slightly raised mass which feels firm to the touch wth a cystoscope electrode. Frequently the urine is not infected. On distention of the bladder the mucous membrane of the involved area fractures, to become visible as fresh bleeding as the overdistention is moderately reduced. This bleeding at first sight is a crisscross of bleeding venules. It is interesting that similar hemorrhage occurs along the length of the superficial blood vessels running to and from the involved area. Repeated instillations of any drug except ⅛ to ½ per cent solution of silver nitrate only irritate the bladder, causing greater bladder pain and frequency of urination. Hydraulic distention of the bladder, and having the patient hold the urine as long as possible by lying upon her back (then

*I feel the best modifications of the Coffey implantation technic are those of Justin J. Cordonnier(33), or of Reed M Nesbit(34), which in both instances eliminate the tunneling principle of the Coffey technic The mucosa of the ureter is cut obliquely by Dr. Nesbit's technic and directly across by Dr Cordonnier's technic.

measure and record the amount each day), supplemented by instillations of silver nitrate, give symptomatic relief. Cystoscopic electrocoagulation frequently gives marked relief. The lesion is seen most frequently in menopausal women. It is very possible that a senile vaginitis associated with the postmenopausal period allows entry of infection to the lymphatic system. This disease occurs infrequently in men. While electrocoagulation benefits in many instances, I prefer to infiltrate these painful fibrous placques with procaine. To do this a long, flexible needle is used through an operating Brown-Buerger cystoscope. The Hunner ulcer area is very firm, so that infiltration needs to begin at its periphery. Soon, however, the entire pathologic area is spongy. The patient then continues her past treatment. Relief is marked, and may last for months. The procedure is applicable to discrete areas of interstitial cystitis. As much as 150 ml. of 1 per cent novacain can be injected into one circumscribed Hunner ulcer. The rationale of the treatment is to markedly reduce the contraction exerted upon the nerves and blood vessels, and the fixation of the mucous membrane to the *muscularis*. *Differentiation between Hunner(19) and tuberculous ulcer is* important. Banthine or Probanthine should be given in all cases of Hunner ulcer, both before and after surgical therapy.

Bladder Stone. Bladder stones are of two types, primary and secondary. The primary stone is formed entirely within the bladder, while the secondary stone, having passed from a kidney, increases in size after entering the bladder. Stone formation etiologically is as varied as the stones themselves. Important in the etiology are infection, foreign bodies, and tissue damage with calcification following a urinary infection which will split free ammonia from urea and so alkalinize the urine. Etiologic in the formation of stones also are alkaline urine from other sources as drugs, food, a high mineralized diet with urinary obstruction, and stasis of urine. Large, soft stones are composed chiefly of calcium, magnesium, sodium phosphates and carbonates, with, however, small amounts of urates and oxalates. We occasionally have a black stone showing a predominance of oxalates at least on the surface of the calculus; this very hard stone cannot be removed transurethrally. The color of a urate salt stone depends upon the amount of calcium in it. Uric acid itself is reddish in color, which color is cut down to a buff or pale pink when considerable calcium salts are present. As uric acid does not absorb x-ray, whenever it is predominant, a small, reddish colored stone can easily be missed in an x-ray examination, there being too little calcium in the stone to cast a shadow.

When stones are removed by open surgery, the removal of the stone itself is not of primary importance, but it should be determined, if possible, why the stone formed, and its etiologic factor removed. It is necessary to search for anything which could cause stasis of urine with or without continued infection of urine. There is no specific danger in opening the bladder and at the same time removing a stone.

Associated prostatic enucleation and removal of a diverticulum and a bladder stone are individual problems If the patient is a satisfactory surgical risk the prostate and stone can be removed at the first operation. A large diverticulum possibly should be removed at a second stage.

Litholapaxy, perfected by Bigelow, and for some cases improved by

the visual lithotrite, is definitely indicated in secondary bladder stones. Large stones, particularly hard stones, the oxalates, cannot be broken by litholapaxy. Frequently litholapaxy with transurethral prostatic revision meets all requirements to effect a cure. A large mouthed(20) diverticulum may be left behind in certain instances. Given a large diverticulum with a small mouth or opening into the bladder, in satisfactory risks, open surgery with diverticulectomy is often desirable.

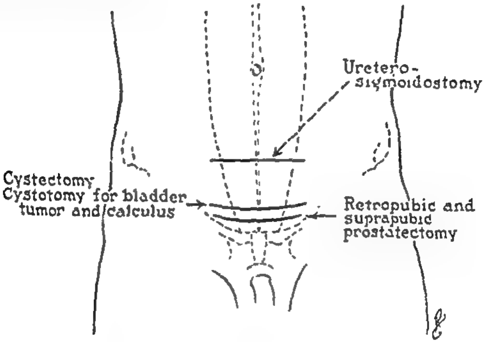

Fig 21-10. Diagram illustrating transverse abdominal incisions for urologic procedures. (*From Presman, Am J. Surg., 83:66, 1952.*)

Bladder Tumors. Clinically it is satisfactory to divide bladder tumors as single or multiple, papillary, sessile or pedunculated, and invasive, noting the depth of invasion. The benign pedunculated papilloma nearly reproduces the bladder epithelium along its fibrovascular stem. The malignant papilloma has a thicker epithelium which shows varying amounts of mitotic figures. It is sessile, of mulberry outline and more vascular as shown by its deeper color than the pale benign pedunculated papilloma. The base of the malignant papilloma must be searched cystoscopically for any bladder wall invasion. If there is none, cystoscopic electrocoagulation, in the opinion of some urologists followed by radon seed implants, 1 millicurie placed around and through the base of the lesion is indicated. Otherwise open surgery with excision is necessary. Deep thorough cystoscopic electrocoagulation without radon seed implant is sufficient to destroy the benign papilloma. A readily accessible tumor when either multiple, too large, or infiltrative is well treated by resection, using the Stern-McCarthy resectoscope. After thorough removal, a second or third resection, for purposes of biopsy, is indicated. If no malignant cells are found the prognosis is hopeful, though always guarded. Both types should be watched for years for possible recurrences. The infiltrative lesion, though small, is far more malignant than the papillary lesion Thorough transurethral resection, cystostomy with wide excisions, or cystectomy with implantation of the ureters into the

sigmoid, is indicated in such tumors. Radon seed implant, open or closed x-ray therapy is desirable additional therapy. Excise all invasive lesions of the bladder, or when too large for excision cystectomy should be considered.

Sarcoma of the bladder is rare. It is extremely malignant; cystectomy or wide excision immediately is indicated.

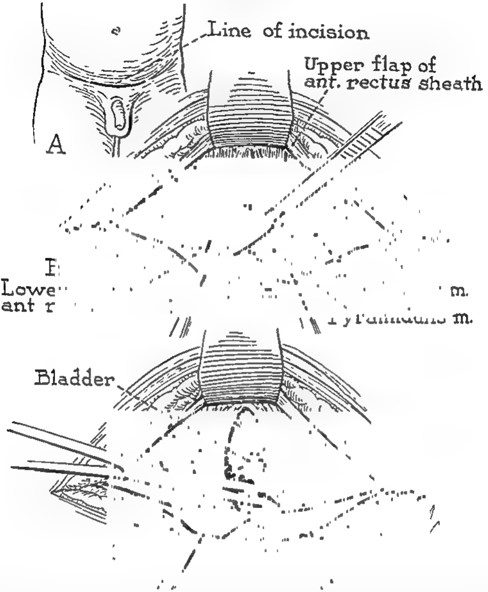

Fig. 21-11 A, line of incision just above symphysis for retropubic or suprapubic prostatectomy. B, rectus sheath has been incised transversely Upper flap of rectus sheath has been freed from rectus muscles Lower flap is being freed Dotted line in lower flap indicates line of incision to be made down to symphysis C, pyramidalis and rectus muscles separated in midline to expose bladder Insertion of recti to symphysis will be incised transversely along indicated dotted lines (From Presman Am. J Surg., 83 86, 1952.)

The great majority of benign bladder tumors are operated transurethrally. Biopsies can be obtained, or a favorably located tumor may be resected, with the Stern-McCarthy resectoscope, or for biopsy the surgeon may use an operating cystoscope with rongeur forceps or a Lowsley or Young rongeur cystoscope. Many such tumors can be destroyed readily by electrocoagulation. When the grade of malignancy is sufficient to warrant it, radon seeds occasionally may be implanted through an operating cystoscope. Regarding implantation of radon seeds cystoscopically, there is

a very important point, namely, that if the base of the tumor shows any invasion whatever, it is probable that this invasion either within the bladder wall or at the outer surface of the bladder wall is more extensive than that seen cystoscopically. For this reason, in such instances open surgery is preferable, providing the site will lend itself to such a procedure. The

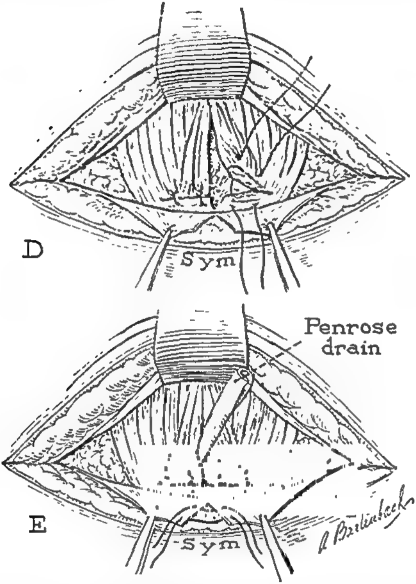

Fig 21-11 (cont.) D, closure of incised rectus and pyramidalis muscles with interrupted sutures E, incised rectus and pyramidalis muscles closed Penrose drain in space of Retzius. Midline incision in lower flap of rectus sheath being closed with interrupted sutures. (From Presman Am J. Surg, 83 86, 1952)

Czerny incision is desirable for this procedure. This incision is transverse across the low abdomen, dividing the erector abdominalis muscles near their tendinous insertion to the symphysis pubis, and gives excellent exposure. A retention urethral catheter placed just before operation frequently is invaluable for the purpose of distending the bladder and so helping the operator palpate the involved area. This is done after complete exposure of the bladder and just before it is opened

Dr. David Presman(43) gives us two illustrations of his transverse abdominal incision for urologic procedures (Figs. 21-10 and 21-11). I quote his article:

"We have used transverse incisions for the following urologic procedures: 1, suprapubic operations (one-stage suprapubic prostatectomy, retropubic prostatectomy, cystotomy for calculus or tumor, cystotomy as a preliminary procedure for transurethral resection, diverticulectomy, cystectomy, total or segmental); 2, transperitoneal nephrectomy; and 3, bilateral ureterosigmoidostomy."

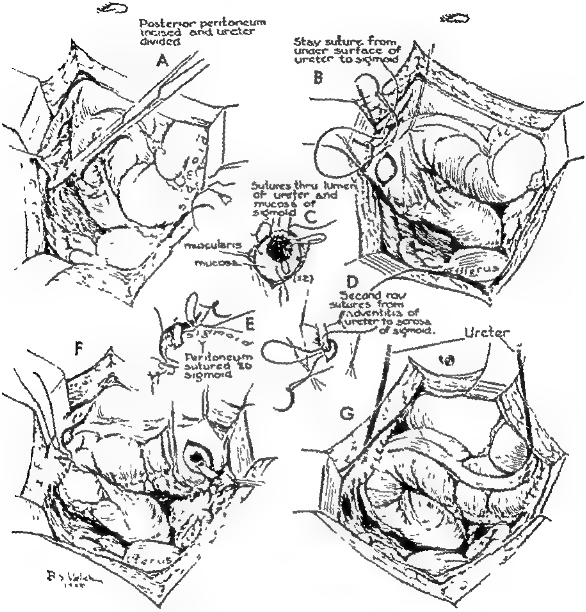

Fig 21-12 Cordonnier's method of ureterosigmoid anastomosis (From Cordonnier, Surg, Gynec & Obst, 88 441, 1949.)

Cystectomy. Cystectomy is of great value, but the decision when to do a cystectomy is a difficult one to make. It is particularly indicated in large, infiltrative tumors and multiple tumors of the bladder; resection may be preceded by bilateral ureterosigmoidostomy or a ureterocutaneous anastomosis and immediate cystectomy, or two to four weeks later the cystectomy may be accomplished through a midline suprapubic incision. The prostate occasionally, and seminal vesicles are removed at this time. The removal of a large amount of normal bladder wall in a case of papillary tumor suggests that less drastic methods could and should have been tried. Partial

resection of the bladder is occasionally indicated when the tumor is located on the dome or free wall, not the base, and when there is no great thickness, as determined by bimanual palpation, that is, with one finger in the rectum or vagina, and the other hand palpating.

Justin J. Cordonnier(42) reports his opinion after two and one-half years experience with ureterosigmoid anastomosis by his mucosa-to-mucosa method, which he presented to us in 1949 (Fig. 21-12). He feels this procedure offers three fundamental principles:

1. Minimal disturbance of the ureter due to the bowel being brought to the ureter rather than the ureter to the bowel.
2. Mucosa-to-mucosa transplant is accomplished.
3. Submucosal tunnel is eliminated.

After surgery Cordonnier advises, and this is in his 1951 report, sodium bicarbonate in doses of one teaspoonful three times a day, to maintain a normal elevation of carbon dioxide. He also advises that the patient empty the bowel at two hour intervals and limit salt intake to that used in cooking. "Ferris and Odel feel that the lowered carbon dioxide is in part due to the hyperchloremia following absorption of chlorides from the large bowel."

Cordonnier advises the use of the ileo bladder substitutions: 1, in those patients with dilated ureters; 2, in all cases of not too malignant disease; 3, in cases of bladder carcinoma with a better than average prognosis. The impression at this time is that longevity may be prolonged by this method of urinary diversion, and that morbidity in general is reduced. The disadvantages of the ileo segment are necessity of an external device for the collection of urine, and the increased technical difficulty in performance of the surgical procedure, with a resultant increase in operative mortality.

Exstrophy of the Bladder. This congenital malformation may be divided into a complete and incomplete bladder exstrophy. In complete exstrophy there is a division of the pubic bone, a complete epispadias, and complete absence of the lower abdominal wall with replacement by the posterior surface of the bladder where the ureteral orifices can be seen ejecting urine. These patients usually have a more or less modified waddling gait, due to the femur being rotated externally. Associated congenital defects may be present. In these instances a Coffey, or modified Coffey, operation (ureterosigmoidostomy) is used for diverting the urinary stream. Later the abdominal defect is closed. An intravenous pyelogram is indicated to determine the status of the upper urinary tract, as markedly dilated ureters may not function well when implanted into the sigmoid.

Other congenital defects are the hour-glass bladder, which may be confused with many atypical types of bladder, such as urachal diverticulum or a winged trigone In any instance we have a division of the bladder in some degree into two separate parts.

Congenital defects of the urinary tract quite accurately obey a rule, that "the degree of malformation determines the age of onset of the symptoms"

Diverticulum of the Bladder. Diverticulum of the bladder may be congenital, particularly when of the urachus. The diverticulum, however, that we see clinically is congenital only in that the bladder has not been woven

evenly with smooth muscle bundles; that is, there is a small area of imperfect musculature through which the mucous membrane can herniate whenever the bladder becomes obstructed. Occasionally normal micturition pressure is sufficient to herniate the bladder mucosa. By overdistending a normal youth's bladder(22) I have been able to demonstrate such mucous membrane herniation in apparently normal bladders. Infection complicates a diverticulum sooner or later and fixes the sac to tissues outside of the bladder. An opening of the diverticulum into the bladder which is large will drain better than the one which is small. This means a large mouthed diverticulum need not necessarily be removed, provided the bladder obstruction is corrected, as against the small mouthed but large diverticulum which certainly will maintain a urinary infection.

A diverticulectomy is performed through a cystostomy. First incise the mucous membrane around the mouth of the diverticulum, then by reaching through its mouth fasten sufficient Ochsner clamps to the bottom and sides of the sac so that it may be everted, providing inflammatory fixation is not too firm. If it is not firmly fixed to its surrounding tissues it will evert quite readily and come out through its mouth. The bladder wall defect is then closed with plain catgut. On the other hand, when it is markedly fixed by infection, it may be necessary to pack it with gauze, then incise the bladder wall down to its mouth, and remove it as an extracystic mass. When the ureter is hopelessly involved in it, ureteral implant into the bladder may be performed, which occasionally is not satisfactory; or the ureter may be tied off providing it is well known that the opposite kidney is normal and that the involved kidney is normal. This is rarely advisable. After removing a diverticulum, drainage may be placed around the side of the bladder to the space from which it was removed. Free bladder drainage should be continued for at least 10 days. Any obstruction to the bladder should be corrected at the time of diverticulectomy. From this standpoint it is well to consider diverticula as herniation caused by some degree of urinary obstruction, although given a congenital weakness in the bladder wall, a diverticulum will occur without this obstruction.

Injuries to the Bladder. In World War II blast injuries to the bladder assumed unusual proportions, although the automobile in civil life remains first in causing bladder rupture. Transurethral surgery, gunshot wounds, punctures by bone fragments, particularly when the pubic bones are fractured, may cause urinary infiltration. Falling upon an overdistended bladder and causing its rupture suggests that some other bladder pathology is associated. Very frequently there is associated damage to other organs. Surgical treatment of bladder injuries is directed toward drainage of urine. This means free drainage, large cystostomies, after which the bladder will collapse and by such contraction close all leaking points. In small injuries a retention urethral catheter may be satisfactory.

Prior to sulfonamides, penicillin, and streptomycin, urine was considered a necrotising agent. However, in many clinical instances it is only the vehicle for infiltrating bacteria. This means less surgical drainage of infiltrated tissues is necessary provided chemotherapy is instituted before necrosis has begun. Intravenous urograms and cystograms may be necessary to determine that leakage of urine is present after bladder injury.

THE PROSTATE

Prostatectomy is never done for infection alone, although most obstructing prostates are infected or, if not, their urethra carries a dormant infection. We classify benign prostatic obstruction as being due to the large soft nodular hypertrophy (the mixed type nodular hypertrophy in lesser degree, with considerable associated scar tissue), and the small scar-tissue prostate. The former large and soft, and the latter small, smooth and of firm consistency. The former is associated with age and hormonal changes, the latter with continued infection plus age changes. The scar type prostate when obstructed is usually associated with a median bar. It is, as a rule, seen earlier in life than the large, soft hypertrophy. There frequently is a blending of these two types of prostatic obstruction, that is, a small benign adenoma appearing in the prostatic urethra after considerable scar formation complicates the fibrous type of bladder obstruction.

In prostatic obstruction back pressure damage to the kidneys corrects to a remarkable degree when the back pressure is released, providing it has not stretched the ureter and kidney pelvis too much, with great thinning of the renal tissue. On the other hand, destruction of kidney tissue by infection is permanent, as its resultant scar within the renal substance shuts off the tubules and the entire nephron is damaged. With infection there is toxic and direct damage by infection to the tubules and to the glomeruli. Very frequently the two types of kidney damage are associated.

The time of development of bladder obstruction by the prostate determines the symptoms that occur throughout this period of the individual's life, and also distinctly influences the degree of kidney damage. Prostatic obstruction which progresses slowly over many years, starting as a fibrous type, and changing into the mixed type as nodular hypertrophy shows itself, will produce a much thicker bladder wall than a rapidly progressing obstruction. It is the bladder wall which fails when the individual can no longer urinate. Or if we put it another way, if the bladder wall could continuously become stronger and stronger, a complete prostatic obstruction would not occur and there would be no need for our surgery, except as the secondary bladder wall changes damaged kidney function and/or the stasis of urine invites infection. A thick bladder wall with its long intramural ureter can be important, following cystostomy or one-stage suprapubic prostatectomy. In such an instance the collapsed bladder can pinch off the ureter sufficiently to account for a sudden uremia. Ureteral catheters passed either suprapubically or cystoscopically and left in for three or four days will correct such complication.

Cystostomy frequently is a preliminary step in the two-stage suprapubic prostatectomy, and in this regard it has gained considerable acceptance on the basis of bladder decompression which was first brought out by Zwalenburg(12). However, kidney damage by back pressure is less serious than by infection, and efforts to decompress often spread infection. Cystostomy often relieves back pressure upon the kidneys. The idea that sudden emptying of the bladder is dangerous because it correspondingly releases pressure upon the ureters, therefore upon the kidney, has not been borne out by practice or by experiment. This false belief has caused

considerable damage. The critical point is that the bladder can be opened with impunity, no matter how full it is, provided free surgical drainage is instituted after it has been opened. Alternate emptying and filling in the presence of trauma spreads infection. It is in this regard that the urethral catheter may be dangerous, particularly when it does not drain well or when a patient is catheterized intermittently.

There are four types of prostatic surgery: 1, suprapubic, one-stage or two-stage. With the latter, a cystostomy is performed, and 5 to 10 days later prostatic enucleation; 2, perineal prostatectomy was perfected by *Young(13), Hinman(14) and Belt(15)*; 3, *transurethral surgery generally* became successful with the Stern-McCarthy resectoscope; and 4, retropubic prostatectomy(29) is now being evaluated. Whenever transurethral surgery can release the patient from his dysuria and his residual urine so that the bladder will empty completely and therefore the urine will clear of infection, it is desirable. Transurethral surgery can be preceded by urethral catheter drainage, provided the catheter drains freely and is well borne, *because the resultant infected prostatic urethra is resected early in the* operation. Suprapubic surgery, with large, soft, benign prostates, as a general rule should not be preceded by urethral catheter drainage, but if immediate drainage of urine is necessary cystostomy should be performed and enucleation done at a second stage. Unrelated complications (of heart, blood, etc.) may make an *indwelling* urethral catheter necessary, at least for a trial. The catheter causes greater bleeding at the time of surgery and predisposes to local spread of infection, particularly an epididymitis. Perineal surgery is desirable in the hands of those urologists who choose it and who therefore perfect their technic. It has been associated with a moderately larger percentage of impotence and lack of urinary control and anal control. Both of these happenings are associated with voluntary perineal muscle function and or with injury to the *membranous urethra* and its fibromuscular support and control. After suprapubic surgery the lack of urinary control seldom follows. If it does, some cause other than the surgery should be well investigated.

Suprapubic prostatectomy(16) is the operation of choice in those not *skilled in perineal surgery in the very large prostate, or when the prostatic* obstruction is complicated by stone, diverticulum or bladder tumor, or very large median lobe

Millin is gaining friends to his retropubic prostatectomy. Among others, Lowsley and Gentile(30) report Millin's method with some modifications in 28 cases. *Hemostasis is controlled by electrocautery and gelfoam wet in* thrombin covering a 24 F. 30 ml Foley catheter. The operation is essentially a one-stage suprapubic procedure, with removal of the prostate through the anterior capsule of the prostate instead of through the usual cystostomy. It is inadvisable in fibrotic prostates, however, if cancer of the prostate is found the gland and *its capsule may be completely removed, together* with at least some seminal vesicle. Special instruments have been devised by Millin which are of definite value in the operation.

Technic of Suprapubic Prostatectomy. The patient is placed upon his back, prepared suprapubically with ether or soap and water and then a skin antiseptic. Drapes are *so placed that a line can be marked from* the

umbilicus straight down to the midsymphysis. Incision is made any desirable length between these points, through the skin, subcutaneous fat, to the heavy, glistening abdominal fascia. The fascia is opened in the midline, exposing the rectus abdominalis and small pyramidalis muscles. The rectus abdominalis muscles are separated by blunt dissection, the pyramidalis muscle being carried to either one side or the other in this dissection. We now expose the transversalis fascia, which is nicked and spread laterally. If the bladder is full, as it always should be to facilitate cystostomy, first fat and then the pale pink crisscrossing muscle bundles of the bladder wall should present midwound. The bladder wall muscle bundles are spread by scissor or forceps points, exposing a bluish mucous membrane. Allis forceps now grasp the opposite edges of the muscularis and the mucous membrane is then punctured. The space of Retzius has been given consideration when spreading and retracting laterally. This space is delineated by a thin fascia extending from the under surface of the symphysis pubis to the anterior wall of the bladder. One single wipe, using gauze dissection, toward and under the symphysis pubis will open it, particularly when the bladder is distended. For this reason skin, fat, muscle and fascia should be retracted laterally and dissected laterally until the crisscrossing pale pink muscle bundles of the bladder are seen. There is one possible danger in opening the bladder wall; if the incision through it is not carried straight forward it is possible not to open the mucous membrane, but to dissect laterally on either side of the incision between the mucous membrane and the muscularis. It is, therefore, well, when the distended bladder is first exposed, to pick it up with strong forceps and hold it in position until it is emptied! A finger is now inserted through the cystostomy opening and the peritoneal fold wiped backward, particularly if a higher exposure of the bladder is desired. The peritoneal fold may be wiped off as far back and laterally as necessary. The peritoneal cavity may be opened, its contents packed off and the anterior peritoneum reattached posteriorly, if necessary to allow resection of diverticulum or tumor. Enucleation of the prostate should be carried out in a specific manner. It is well to insert the finger into the urethra, break anteriorly through the mucous membrane, between the two lateral lobes, then force the tip of the finger between the prostatic capsule and a lateral lobe and pull upward so that the mucous membrane stretching from bladder down into the posterior urethra is tented over the finger. The finger is now moved over the top of the lobe down into the prostatic urethra thereby breaking off the mucous membrane within the prostatic urethra. By repeating this procedure all the way round after enucleation of the prostate we leave tabs of mucous membrane hanging down into its cavity, which, with blood clots and with subsequent contraction of the internal orifice of the bladder and of the prostatic capsule after enucleaion has been carried out, is very efficacious in preventing postoperative hemorrhage (*Figs. 21-13 and 21-14*). These conditions render the necessity for postoperative pack or distensible bag or catheter quite unnecessary except in a few instances. We are anxious to prevent fracture of the mucous membrane at any point away from the internal bladder orifice, that is on the flat floor of the bladder where subcutaneous vessels may persist in bleeding, even after packing the prostatic

capsule. We prefer the one-stage prostatectomy to the two-stage except when surgical judgment dictates that urinary drainage alone should be effected for relief of extreme toxicity, or when cardiac decompensation, fatigue, malnutrition, uremia, etc. are present.

Cystoscopic examination a few moments before surgery does away with the reaction that may occur when the cystoscopy is performed the day before surgery. When the individual is very ill and the prostate is large,

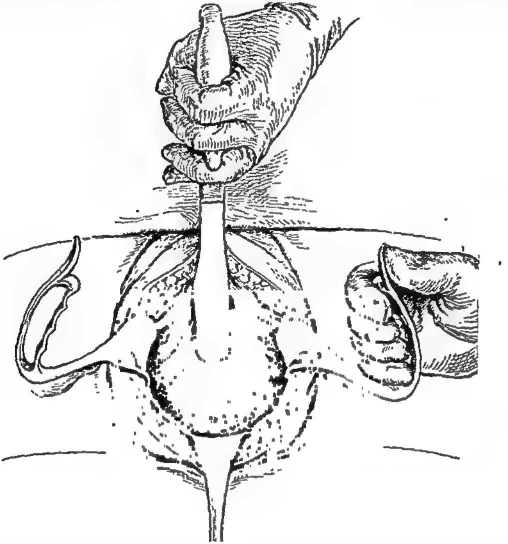

Fig. 21-13. Retractors of Illyés are shown in this drawing. The rake retractor pulls the lower portion of the bladder tight against the symphysis pubis, while the two angular retractors spread the bladder laterally, and the duckbill presses down and backward the open dome or the posterior wall for viewing. With good lighting this method, if the bellywall is not too thick, can be equally as satisfactory as a systoscopic examination Ribbon and Richardson retractors may be used for this exposure

it may be well not to cystoscope, but to observe the interior of the bladder at the time of surgery. Even this may not be necessary. A small nick can be made in the full bladder, the finger quickly inserted to slow its emptying, and its interior palpated as it empties. It is surprising how satisfactory this method can be, but it is decidedly preferable to have a complete preoperative diagnosis. A preoperative intravenous pyelogram may yield much information regarding the amount of prostatic obstruction, if the patient is asked to void before the last film; the shadow cast by the residual urine

containing the opaque material indicates the amount of obstruction. When a two-stage suprapubic prostatectomy is performed, a large retention catheter placed suprapubically through a small stab bladder wound to

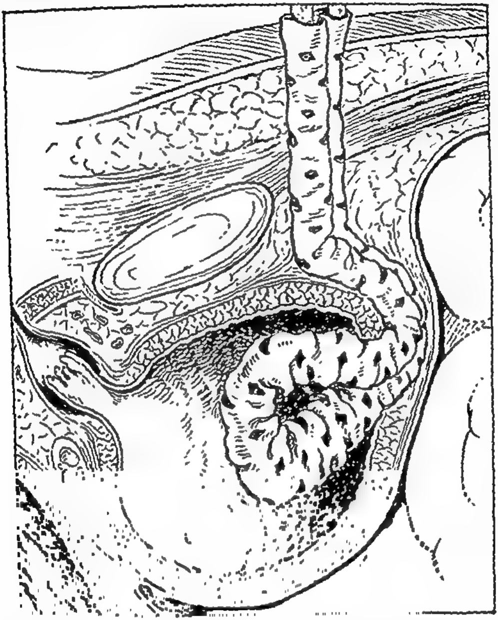

Fig. 21-14. This figure diagrammatically shows a broken urethral mucosa hanging down into the prostatic urethra, at least the bladder mucous membrane is not broken off at a point away from the internal orifice where it can bleed, even if the surgeon uses a distensible bag, catheter or a pack. Contraction of the prostatic capsule in this manner of prostatic enucleation aids greatly in hemostasis, so that hemostatic packs or bags are rarely necessary. A doubled Penrose drain, reinforced with umbilical tape, is shown emerging from the top of the bladder. It is brought out and over the anterior wall of the bladder and on out through the bellywall at a point lower than the sutured bladder incision. With this situation as the bladder fills, these two openings of bladder and bellywall become more widely staggered. The drain is removed on the fourth day. A urinary antiseptic is used. Urinary infiltration is much less important since we have been able to sterilize the infiltrating urine.

reduce leakage will allow later cystoscopic examination, or a cystogram, before the second stage, prostatic enucleation, then the abdominal wound can easily be broken open with a finger up to 10 days.

The scar of incision in a pendulous abdomen will fall down and under

when the patient stands and will become located on the supporting floor of the abdomen, therefore it should be closed with an addition of three or four stay sutures, which are removed 6 to 8 days after the removal of the skin sutures. In this location an incision which has healed slowly may with years herniate slowly, due to the constant strain of an abnormal intra-abdominal pressure resting directly upon the scar.

Hard rubber drainage tubes are used in many clinics; they can produce secondary hemorrhage by their contact with the surface of the bladder or by reaching down in the prostatic capsule. For this reason we prefer a

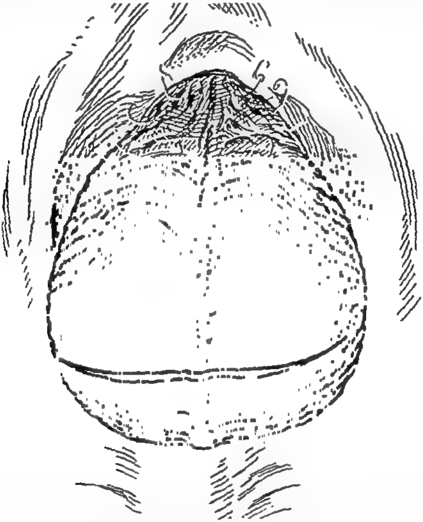

Fig. 21-15 Partial, or intracapsular, orchiectomy in carcinoma of the prostate is at times more desirable than castration, which removes the lower spermatic cord and epididymis. Our incision is across the bottom of the scrotum, the left hand of the surgeon meanwhile squeezes its base and forces the testicles tightly against the skin.

large Penrose tube, reinforced with two lengths of umbilical tape; windows are cut in the side of the Penrose tube, not to facilitate drainage but to help prevent its extrusion by a contracting bladder.

This drain is folded, its ends pinned together, and so introduced well into the bladder. Being pliable, it can emerge from the bladder wall at a high point, folded down upon the bladder wall surface below its incision, and emerge through the abdominal wall at the lowest point of a well closed incision; this staggers the drainage tract more and more, as the filling bladder carries its opening above the abdominal wall opening, which can

be sewed in rather snugly and yet furnish sufficient space for drainage. A direct short drainage tract, from bladder to skin, may delay early closure of the cystostomy.

Very rarely injury to the pubic bone and its periosteum may occur at surgery or by hard drainage tube, resulting in an osteitis pubis.

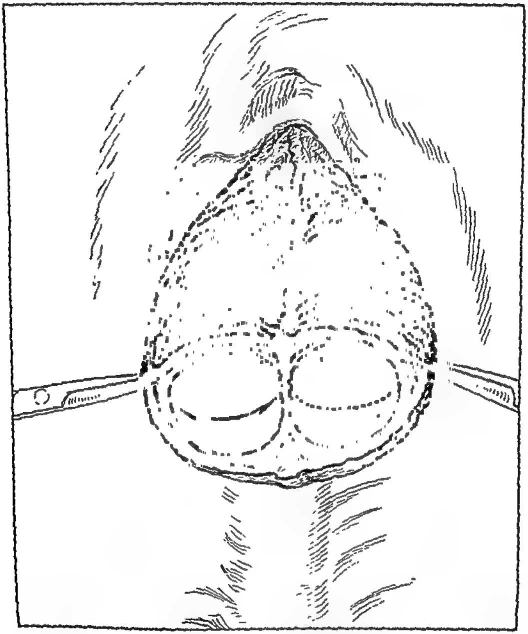

Fig 21-16 Continued pressure at the base of the scrotum extrudes the testicles through the skin, fascia and tunica vaginalis Allis forceps are more desirable than the forceps shown, to grasp and hold skin, fat, fascia layers together for better closure.

Types of suture deserve special consideration, for instance, stainless steel or silver is not as desirable as nylon, linen or deknatel. The former may furnish pathways for drainage of urine, while the latter are more closely fibrosed into the surrounding fibrous tissue and so do not furnish avenues for transmission and infiltration of urine. Stay sutures are very desirable and should be left in for 10 days. However, they alone are not sufficient. The abdominal wall should be closed in layers with 2-20 catgut.

Silk may be used in skin closure, if so the ends should be left long, as medium silk can become buried in the edematous skin associated with urinary drainage. A surgeon may prefer catgut for skin closure for this reason. Closure of muscle, fascia and fat (each row of sutures picking up

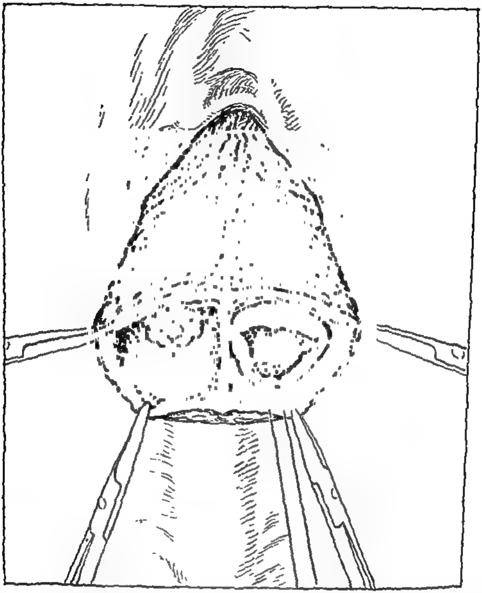

Fig. 21-17. Pressure of the left hand continues to hold the testicles in place while the *visceral layer of the tunica vaginalis is opened when testicular substance extrudes, which is* now wiped out and away from its attachment at the rete testis Hemorrhage is controlled by using No. 000 plain catgut, the first stitch through the vascular pedicle and rete testis attachment, *then continued sutures up the tunica, finally closing its cut edges* Testicle on the right shows the end result, through-and-through sutures, then quickly close the scrotal opening without drainage The weight of the epididymis, fascia, and tunica mass gives a better end *result than complete* orchiectomy from the standpoint, in selected cases, of the patient's psychology In an occasional case complete removal of testicle and epididymis is desirable and does not create a psychological problem for the patient

tissue of the closed layer below) from the drainage tract out will prevent wound infiltration and therefore secondary points of leakage after the cystostomy drain is removed.

Carci... to remove a carcinoma of the prostate ... ounding tissues has occurred.

Prior to such a spread of the carcinoma, though such a one infrequently is seen, complete radical perineal prostatectomy of Young(17) is advisable. After this operation there is a possible 5 per cent cure for five years.

Since the work of Huggins(18), castration and stilbestrol have improved the situation of these cases. Particularly after castration there is a definite sense of well-being, which is very definite but less marked after giving stilbestrol (Figs. 21-15, 16 and 17).

Duration of life since the work of Huggins has been prolonged for variously estimated periods, from 18 months to three and a half years as an average. The acid phosphatase test below 10 units is unreliable as a diagnostic test, though when over 10 King Armstrong units per ml. of blood serum is present, it is almost diagnostic. The alkaline phosphatase test should be done for scientific interest. Palpation of the prostate is diagnostically about 80 per cent correct. Biopsy of the prostatic tissue before enucleation of the testicles can be done best by use of the McCarthy resectoscope. Even so, however, the presence of carcinoma of the prostate in tissue removed by this method may not show carcinoma, as the bites may not reach sufficiently deep; such a biopsy does reach the posterior capsule of the prostate where the malignancy frequently starts. A needle biopsy obtained through the perineum may be more satisfactory than one obtained by transurethral surgery as the malignancy in the early stages may be limited to the posterior lobes directly below the capsule.

SEMINAL VESICLES

Seminal vesicles vary greatly in size and shape; they may be from 1 to 1½ inches long, with a capacity quite equal to the rare one which is 6 inches long. The latter is somewhat smaller than a pencil and may be straight or branched. For this reason, perineal surgery of the seminal vesicles for therapeutic purposes often is unsatisfactory; it is even impossible always to be sure that one is palpating the seminal vesicles. Injection of the seminal vesicles by way of the vas deferens had some measure of popularity, and in some well selected cases may occasionally be indicated. Injection of the seminal vesicles by way of the ejaculatory ducts in well directed research is useful, but it is not a successful clinical procedure. Removal of the seminal vesicles by the perineal route is not a popular operation, however, it can be done in selected cases, though is practically never indicated today. Seminal vesicles are, however, occasionally important from the standpoint of local infection, and the best way to prevent seminal vesiculitis, vasitis, and epididymitis is to control infection before instrumenting the urethra, and to omit unnecessary intermittent or retention urethral catheters. Tuberculous epididymitis is a surgical disease; it may be acute but usually is chronic, fibrous, with skin fixation and later sinus formation.

SCROTUM

Epididymectomy is accomplished through a long lateral scrotal incision. First isolate the vas deferens, cut at the external inguinal ring, or as high as possible by exerting traction at this point, tie each end, deliver the

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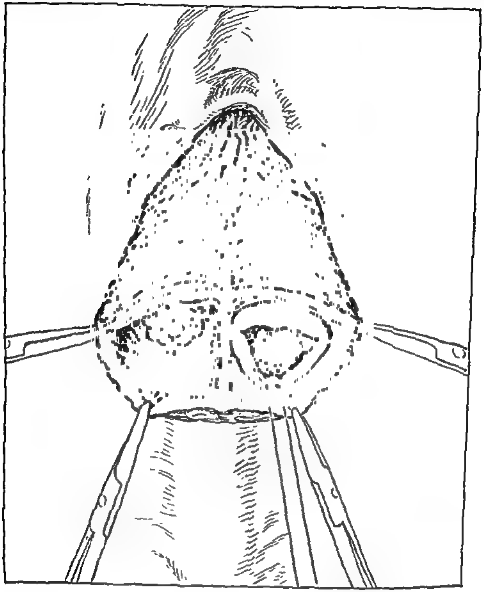

Fig. 21-17. Pressure of the left hand continues to hold the testicles in place while the visceral layer of the tunica vaginalis is opened when testicular substance extrudes, which is now wiped out and away from its attachment at the rete testis. Hemorrhage is controlled by using No. 000 plain catgut, the first stitch through the vascular pedicle and rete testis attachment, then continued sutures up the tunica, finally closing its cut edges Testicle on the right shows the end result, through-and-through sutures, then quickly close the scrotal opening without drainage. The weight of the epididymis, fascia, and tunica mass gives a better end result than complete orchiectomy from the standpoint, in selected cases, of the patient's psychology. In an occasional case complete removal of testicle and epididymis is desirable and does not create a psychological problem for the patient

tissue of the closed layer below) from the drainage tract out will prevent wound infiltration and therefore secondary points of leakage after the cystostomy drain is removed.

Carcinoma of the Prostate. It is impossible to remove a carcinoma of the prostate suprapubically after fixation to surrounding tissues has occurred.

defines the seminoma of Chevassu as an embryonal carcinoma. The teratoma is a complex tumor which may show elements of three original germinal layers. In it we may find hyalin cartilage, thyroid tissue, etc., even chorionic villi from which may develop a malignant chorioepithelioma. Dermoid cysts within the scrotum are rare, of the testes itself very rare. In teratoma often there is considerable confusion as to whether the involved testicle has been large from infancy, or whether the growth started recently. When there is not a definite history of syphilis with or without a positive Wassermann, more lives will be saved by radical surgery than by procrastination. It is unwise to be led astray by a prolan A test. These tests are not sufficiently accurate to warrant surgical procrastination. Our best results have been obtained by immediate orchiectomy in instances when a tumor has definitely increased in size and is a solid mass, even before the exact pathology is known. At operation a longitudinal incision is made in the upper scrotum; through this incision clamp and cut each end of the spermatic cord, enlarge the incision as necessary, and remove the tumor mass by finger dissection. Close the incision without drainage, except as individually necessary for capillary bleeding. It is possible that occasional removal of a gummatous testicle is compensated for by the lives saved by this method of immediate surgery. The tunica vaginalis and even the fascial layers of the spermatic cord and scrotum should be removed en masse, because wandering malignant cells are found in the tunica vaginalis in seminomas.

Undescended Testicle. An undescended testicle should be operated on when Antuitrin S, through its action of hastening puberty changes, does not bring down the testicle. This should be done near puberty, not in infancy. Withdrawal of Antuitrin S after prolonged use in infancy may later interfere with spermatogenesis. In these cases it means that either the blood vessels or the vas deferens is too short, that the internal or the external ring is too small, the testicle large for passage through normal rings, or that descent from its embryonal position has not occurred or is incomplete —a cryptoxid testicle. Occasionally the spermatic cord prolapses through the internal ring, and is palpable in the inguinal canal. In such a case the testicle is too large, actually or relatively, for the internal ring, and the cord alone descends.

The incision for undescended testicle is as for an inguinal hernia and the operation essentially the same, except that every effort is made to elongate the spermatic cord by teasing out, and thereby straightening, each separate blood vessel; if then the vas deferens is too short it may be cut. All shortening fibrous tissue bands can be felt if the testicle is placed in the hand, and with the index finger pressure is exerted against the spermatic cord. By this movement as each band is found it can be teased out, and frequently a seemingly impossible situation can be corrected. The partial failure in a great many of such instances is that the testes retract high in the scrotum after the surgery. If the external ring, however, has been closed well it will not enter the canal but may be in a precarious position near the symphysis pubis, and there subjected to injury. There is also a matter of temperature for correction of spermatogenic function. When it is out of the scrotum this function does not return. The time of operation should be before and close enough to puberty that Antuitrin S may be tried, before

testicle. Dissect upward from the lower pole, then downward from the upper pole respectively the globus minor and major, carry this dissection to within 1.5 cm. of the central attachment to the scrotum. Now use scissor gauze dissection from anterior and posterior surfaces. Tie blood vessels of the epididymis as they are exposed. This procedure prevents damage to the blood vessels of the testicle, and therefore its subsequent atrophy. Marsupialization of the proximal end of the vas deferens to the skin may facilitate drainage and healing in some cases.

Carcinoma of the seminal vesicles is infrequent; its surgical approach is by way of the perineum, as in perineal prostatectomy; its removal is infrequently possible.

Varicocele usually occurs on the left side, by reason of that spermatic vein having a longer course to reach the renal vein. There is the other factor of unusually thin-walled veins. The large varicocele may be removed, when it is either by its weight or its mass undesirable to the patient. However, the moderate varicocele in the young usually does not require surgery. At operation for varicocele a lateral scrotal incision is made, exposing the spermatic cord. A mass of veins is isolated and a section 2 to 3 cm. long should be excised between clamps. Each end is tied and then these ties tied together, thus shortening the spermatic cord.

Small, dense smooth cystic masses which do not transilluminate and are along the course of the vas deferens or epididymis are spermatoceles. A large spermatocele is usually a primary hydrocele that has established an opening with the vas, or the epididymis.

Hydrocele in the young is frequently associated with hernia, at operation a search should always be made for a hernial sac. Idiopathic hydrocele is of unknown etiology. It frequently occurs in men in the prostatic age. It may be associated with tumor, epididymitis, or injury. Recently statements have been made that testicular atrophy following mumps is due to pressure of the small, tense inflammatory hydrocele(23) which if drained immediately will prevent the secondary testicular atrophy.

Operation for hydrocele is carried out by delivering it through a lateral scrotal incision, opening it, the sac everted. The free edges of the then resected redundant sac are united by fine catgut suture. These whipped edges are sewn together in an everted position. The wound is closed without drainage.

Volvulus of Testis. Volvulus of the testicle and spermatic cord occurs suddenly, with severe pain and usually associated with some rather violent physical effort. The scrotum presents a tender, edematous mass, which may of its own accord correct, but even so, it is likely to occur again. Surgery must be immediate, otherwise strangulation will cause atrophy of the testicle. When volvulus occurs and the testicle is undescended, diagnosis can be very readily confused with strangulated hernia. At surgery if an attempt should be made to correct the vascular strangulation, the testicle should be fixed in normal position to scrotal tissue. These plain catgut sutures should not involve the epididymis Orchiectomy is frequently necessary.

Tumor of the Testicle. In tumors of the testicle(24), seminoma, sarcoma, teratoma, and chorioepithelioma, we fear extreme malignancy. Ewing

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given by Horn and *Nesbit*. *Carcinoma* of the penis is infrequent. Radiation of either of these tumors, urethra or penis, is unsatisfactory. Excision of the inguinal lymph nodes is advisable.

Strictures of Urethra. The majority of urethral strictures at present, excepting war injuries, are most frequently of gonorrheal origin. An anterior stricture is much less obstructive than a posterior stricture, as in the latter case the fibrous tissue fixes itself to the urogenital trigone and also may involve the membranous urethra. These fixed posterior strictures are inelastic and do not dilate as easily nor respond as long or as well to dilatation as do the anterior urethral strictures, located in the more elastic penile shaft.

Traumatic strictures not associated with war injuries were, before the automobile, most commonly seen as a result of falling across a fence or wagon wheel, in which cases the perineum received a crushing injury. Today they are more frequently associated with automobile accidents. In children the results are frequently unsatisfactory. It is necessary that these injuries be repaired as quickly as possible from the standpoint of *hemorrhage and urinary infiltration* and therefore the resulting scar tissue, which may continue an obstruction even after the continuity of the urethra has been reestablished by surgery. The most difficult traumatic stricture to correct satisfactorily is one located at the bulbous and membranous urethra. These unsatisfactory results may be due to actual stricture, periurethral infiltration or lateral displacement with fixation of the urethra so that the bulbous urethra is not directly aligned with the opening of the membranous urethra. These cases should be operated as quickly as possible by perineal section, a urethral catheter inserted, continuity of the urethra established, and drainage instituted for both hemorrhage and leakage of urine. Cystostomy with free drainage should be continued for 10 days.

When the injury occurs in an infant, and the results of our surgical attempts are unsatisfactory with or without cystostomy, as may prove necessary in the individual case, it may be well to institute suprapubic drainage for a few years. Then again surgical correction of the stricture or misshapen urethra may be attempted by removal of that portion of the urethra which is involved, and by regeneration of a new urethra. Healing should be over an indwelling urethral catheter

Urethrocele. The residual urine caused by a urethrocele, a urethrocystocele, or a urethrocystorectocele, *is very important in urology* (25). The associated spastic internal orifice and/or meatus, with possible secondary hyperplastic mucosal changes, or the acute cystitis will remain while *the etiologic factors remain*. The perineal muscles, which voluntarily lower the bladder orifice to initiate urination, the urogenital trigone from which their movement is limited, and fascial attachments of the urethra and bladder often are damaged by childbirth; all singly or in association may drop the internal bladder orifice. This defect often exhibits itself by stress incontinence For cure of this distressing symptom, and for elimination of a residual bladder urine, the posteriorly tipped bladder, associated with the damaged perineum, must be raised by surgical repair of the perineum. The anterior bulging cystocele increases by straining (cystocele), which pushes the urethra and meatus upward from a straight to curved (urethrocele) position by anterior perinorrhaphy, and the associated contraction of

advising surgery. We do not expect normal spermatogenic function in either the intra-abdominal (cryporchid) or undescended testicle. This is due to the abnormal temperatures to which these testicles are subjected. Recurrent mild trauma to the undescended testicle may be a factor in its tendency to become malignant.

The Torek operation and its modifications have been a distinct help. In this operation the gubernaculum testis is brought out of the lower part of the scrotum, sutured with silk, either directly to the thigh or to a rubber band sutured to the thigh.

Because of the danger of malignant degeneration in an undescended testicle is always to be considered at operation when it cannot be brought down properly and the other testis is normal, that excision of the malplaced testicle may be advisable.

URETHRA

A diverticulum of the urethra may be congenital, however, such malformations are less frequently found than those that follow periurethral abscesses. Either type predispose to infection by interfering with proper emptying of the urethra and possibly of the bladder. They should be removed surgically. This is best accomplished by perineal or penile section; in the former, an incision parallel to the urethra is made over the diverticulum after the patient is placed in extended perineal position. The diverticulum is dissected free, excised, and its attachment to the urethra closed with interrupted catgut sutures. A urethral catheter should always be inserted; it may in a few instances prove unsatisfactory for urinary drainage purposes; then suprapubic cystostomy will have to be performed.

Carcinoma of the urethra occurs infrequently; it extends first to the inguinal lymph nodes. We see this disease in both male and female. In the female it must be differentiated from carcinoma arising from tissues near the urethra. In the male, fortunately, this carcinoma is extremely rare; its prognosis is very poor. The prognosis is better with the female urethral carcinoma.

Urethroscopic examination is necessary in all instances of urethral bleeding. In urethral cancer the greater amount of blood is found in the first glass of a voided two glass urine specimen test. Frequently, blood appears at the meatus.

Carcinoma of the penis should be differentiated from carcinoma of the urethra; the former may occur as a result of a prolonged irritation. Epithelioma of the glans penis prepuce is ulcerative in its incipiency; it progresses rapidly with considerable variation in its effect upon the prepuce. These malignancies metastasize by way of the lymphatics first to the inguinal and then to deeper lymph nodes. For this reason, at operation, incision of the penis within a centimeter of the edge of epithelioma is permissible. When the carcinoma is located in the anterior half of the penis it is unnecessary to do a radical excision of the entire penis! When the carcinoma has invaded the penis in its entirety, radical excision can be performed by amputating the entire organ, bisecting the scrotum, and bringing the urethra out in a perineal position. The over-all mortality rate varies, in carcinoma of the penis, from 8 per cent by Young, to 31 per cent

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the meatus dilated by an associated contraction of the internal orfice of the bladder, requires transurethral resection. When these changes occur the membranous urethra may contract and require dilatations, as high as 45 French, with either a Kollman dilator or graduated dilators or catheters. Passive congestion anterior to the membranous urethra, a mass of dilated blood vessels, may appear at the urethral meatus—a caruncle—if large, they may obstruct and need excision. Grasp with forceps and excise in a line parallel to the long axis of the urethra. Or the urethral mucosa may evert. The proper direction for cure is correction of the urethra, and/or cystocele and/or rectocele, the associated hyperplastic urethritis, contracted internal orifice—not repeated excision of a caruncle!

The curve of the urethra is a urethrocele, associated with or without a cystocele or a rectocele. Absence of certain muscles of the trigone and fibrous attachments may be congenital, therefore cystoceles and urethroceles may be seen in virgins. They may occur shortly or years after childbirth. Increased fat (weight) within the abdominal cavity, with greater downward pressure and therefore greater sag of the bladder base, accounts for bladder infection 20 to 30 years after the damaging childbirth. The cystitis occurs because of a residual urine inviting infection. Hematuria, with pain, occurs most frequently in this type of cystitis.

Surgical repair of all defects is necessary(26). The meatus must be drawn down, and to do this the suture line of repair must begin *at* the meatus and extend back to the cervix. A normal perineum, furnishing a foundation for the floor of the bladder, must be reestablished. When all is done there may remain a damaged trigonal muscle, which cannot be repaired. Stress incontinence, almost a pathognomonic symptom of cystourethrocele is, at surgery, best relieved by suture elevation of the internal bladder orifice and posterior urethra. Mattress sutures fixed to the vaginal mucosa and passing through the floor of the internal orifice are important. This may permit the continuation of a contracted internal orifice, which in consequence rubs upon itself to create in the upper half of the internal orifice various papillary excrescences, or inflammatory tabs, which in our knowledge of the physiology of micturition we realize reflexly stimulate the bladder to contraction, and therefore stimulate frequency of urination when the urine itself is not infected.

Referred pain from the contraction of the internal orifice(44) may be in either groin, or abdomen, perineum and the urethra. The hyperplastic mucosal tabs are best destroyed by cystoscopic electrocoagulation.

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INDEX

INDEX